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Hypothetical Correlation Model Between Mluku as Local Wisdom and Its Contribution for Lunar Mining

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Abstract**—** *The advancement of space technology, such as establishing a refueling station for rockets to enhance their travel capabilities, has led to a need for a habitat on the moon. Creating such a habitat on the moon is necessary, considering the high costs associated with transporting materials from Earth. As an alternative, extracting materials from the moon itself has become a viable consideration. This paper introduces a method inspired by Indonesian traditional knowledge called Mluku, aimed at loosening lunar soil. This approach is akin to the Prepacked Aggregate technology, previously suggested for mixing concrete on the moon, which stands out for its energy efficiency. The Mluku technique is rooted in the idea of employing more simplistic equipment, mainly when working in conjunction with robotic technology- the combination of both is expected to simplify the design of control mechanisms. Drawing insights from various global space initiatives, there is confidence in the competitive advantages of the Mluku approach, both in terms of reducing payload weight from Earth and enhancing the control mechanisms for worker robots.*

Keywords**—** *Lunar habitat; Material; Mining; Mluku; Robotic; Space technology.*

I. INTRODUCTION

Agriculture (cultivation of crops and or livestock) is one of the earliest endeavors known by human civilization and has totally changed the form of culture. Agriculture has been known by people since the New Stone Age (Neolithic), Bronze, and Megalithic ages (Arwati, 2018). In general, agriculture is considered to have started as a result of global climate change and plants' adaptation to this change. Prehistoric experts generally agree that agriculture first developed from cultures in the "fertile crescent" region in the Middle East, which included the Tigris and Euphrates River valleys extending westward to present-day Syria and Jordan (British Museum, 2016).

One of the tools in agriculture activity is the plow, which is used to loosen the soil before planting and sowing the seeds. Since humans began farming activities approximately 11,500 years ago, plowing has been done mostly by using sticks or hoes (Britannica, 2018). Artifact evidence of the use of a plow called the ard in the middle Neolithic period has been found. At first, the ard was pulled by humans, but later, after humans began to domesticate animals, the ard was pulled by a cow, horse, or buffalo (Mallory & Adams, 1997). The plow continued to develop in terms of material, design, and method of operation. Innovations continued to be made in order to obtain maximum agricultural yield and at the same time to make humans work more efficiently. One traditional agriculture tool, especially for the Javanese people, that is still in use today is the *luku*.

A *Luku* is an agriculture tool made of teak or jackfruit wood. These two types of wood are strong. Luku is made of several components, namely *pengadang, srampat, racuk, and aling-aling. Racuk* at the base part consists of *singkal, kejen, bantalan, pengiwa, pengandap, buntut,* or *kepet.* The function of the luku is to plow the field to make the soil loose and the grasses become covered by the soil turned upside down by the plowing action of the *luku* (Asmara, 2017). Field plowing activity by using *luku* is called *ngluku* or *mluku. Mluku* has a cultural meaning of *ngluruske laku*, which means to straighten the attitude and action in the context of leadership. The function of *luku* is to stir and crush the soil. This becomes a symbol of a candidate leader who is expected to change things for the better in order to create a harmonious and balanced community (Wahyuni, 2017).

Technically, a *luku* is operated by a person who uses *cethen* or *cemeti* to lead the two cows or buffalos that pull the *luku.* The end of *luku* made of a triangle-shaped metal called *kejen*, is then connected to bamboo blades to the left or right, before it is pulled by the animals. The purpose of this action is to loosen the soil by turning it upside down. By using *luku*, the texture of the soil becomes smoother than when using a tractor. As a result, the soil is easier to work on compared to using a heavy tractor that uses chemical fuel that can slowly contaminate the soil and reduce its fertility.

In the last two decades, the rumor about mining on the moon started in 2007. The X Prize Foundation, together with Google, launched a moon commercialization effort with a total prize of 20 million USD for those who could reach the moon with a robot by March 2018, with an additional prize of 10 million USD for the next achievement (Chang, 2017). As of August 2016, 16 teams were registered to take part in the competition, but as of January 2018, the X Prize Foundation announced that the prize would not be won by anyone because no team had managed to do a launch within the specified deadline (Wall, 2017).

In August 2016, the United States government gave the permission for Moon Express to land on the moon (Wall, 2017). This moment was the first time that a private company was given approval by the state. Previously, private companies were given limited permission to carry out space activities. On November 29, 2018, NASA announced that nine commercial companies would compete to win a contract for the delivery of a small payload to the moon known as Commercial Lunar Payload Services. According to NASA administrator, Jim Bridenstine, this effort was for building the United States'

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domestic capability to shuttle between the earth and the moon (Chang, 2018).

Long before that, China launched the Chinese Lunar Exploration Program to explore the moon and investigate lunar mining possibilities, particularly for the purpose of mining helium-3 isotopes for use as an energy source on Earth (David, 2003). China then launched a robot called Chang'e 1 in October 2007 and it was so successful that the exploration was extended for several months. This Chang'e 1 success was followed by Chang'e 2, Chang'e 3, (Clark, 2018) to the most recent Chang'e 5, which returned in 2020 with two kilograms of sample taken from the lunar surface (Amos, 2020). Besides that, the Indian space agency, the Indian Space Research Organisation (ISRO), was also involved in the launch of Chandrayaan-1 in 2008 to perform a mapping of resources on the lunar surface (Bagla, 2008). The success of Chandrayaan-1 was followed by Chandrayaan-2 in 2019.

If mining on the moon is performed, a number of positive and negative impacts come to mind.The positive impact is that humans gain access to new natural resources that can sustain human life after the earth's natural resource deposits have been depleted. The negative impact is that there is a massive exploitation that occurs not only in the earth's environment but also outside of the earth. This certainly threatens the balance of the ecosystem. On this basis, an idea is required that not only is able to provide technical input regarding the form of lunar mining that is "non-destructive", but also philosophically offers a consideration to keep observing the harmony between humans and the environment to prevent excessive exploitation. In this case, the Indonesian local wisdom offered for lunar mining is Mluku.

II. METHODS

This study involves qualitative research to develop a model that showcases the connection between traditional knowledge and its integration into modern technology. In this context, "local wisdom" pertains to the practices of *Mluku*, while its utilization of advanced technology relates to lunar mining operations. Qualitative research is a methodical approach involving the gathering, structuring, and analyzing of written or spoken data obtained from interviews or observations. This type of research is employed to explore the significance of social occurrences as they are perceived by individuals within their everyday surroundings (Malterud, 2001). Meanwhile, a model is defined as a representation of an object, article, or ideas in a simplified form of a natural condition or phenomenon. A model contains information on a phenomenon that is made in order to study the phenomenon of the actual system. A model can be a mock from an actual object, system, or phenomenon that only contains information that is considered important to be analyzed (Achmad, 2008).

Data in this research is collected through literature study, by analyzing research on *mluku* and lunar mining activities. The result of the research will be a hypothetical model or one that is possible to be proven or applied in the future, such as the making of concrete on the moon by using the Prepacked Aggregate method, inspired by the construction of Borobudur Temple in the 8th century. (Munaf & Piliang, 2020). Local wisdom has been used for the global community in the last few years, because diffusion of technology based on the Local Wisdom Method is utilized by the community more quickly because it has been known culturally. (Simajuntak & Chintia, 2022).

For a start, data will be gathered on possible resources available on the moon according to studies by scientists collected from a number of research papers. After that, lunar mining efforts that have been made by certain countries will be discussed, including the legal aspects and the technology employed. All information regarding this matter will be compared with the soil conditions, especially in Indonesia, when plowed by *luku* in *mluku* activities. The comparison will be arranged in the form of a hypothetical model of the use of *mluku* activities for mining along with the advantages, obstacles, and possible positive and negative impacts.

III. DISCUSSION

The study's discourse will rely on existing literature concerning potential natural resources on the moon and the legal regulations surrounding mining activities. Then, the discussion will explore the feasibility of applying the *mluku* concept to lunar mining. The research will culminate in creating a hypothetical model designed to encapsulate the overarching concept.

3.1 Natural Resources on the Moon

The moon, according to scientists, has a great deal of natural resources. Based on studies on lunar rocks brought back by the Apollo missions, scientists have learned that the moon is rich in minerals. The overall composition depends on whether the rocks originated from the *mare* area (large, dark, basaltic plains formed by asteroid impacts on the moon) or the plateau. Rocks extracted from the *mare* area show large traces of metal, 14.9% alumina (Al^2O^3), 11.8% calcium oxide (lime), 14.1% iron oxide, 9.2% magnesium (MgO), 3.9% titanium dioxide (TiO^2), and 0.6% natrium oxide (Na^2O). From the lunar plateau, a similar composition was obtained, namely 24.0% alumina, 15.9% lime, 5.9% iron oxide, 7.5% magnesium, and 0.6% titanium dioxide and natrium oxide (Hananto, 2020).

The same study also showed that lunar rocks contain a large amount of oxygen, especially in the form of oxidized minerals. Experiments have shown that oxygen can be extracted to provide breathing air to astronauts. It can also be used to make water and even rocket fuel. The moon also contains concentrations of Rare Earth Metals (REM). On one hand, REM is becoming increasingly important for the global economy, because they are widely used in electronic devices. On the other hand, 90% of REM deposits are currently controlled by China; therefore, permanent access to outside resources is perceived by some as a national security issue, especially for the US. Similarly, the moon has a large amount of water contained in the regolith and dark areas permanently at the north and south poles of the earth's satellite. The water is also valuable as the source of rocket fuel, not to mention as drinking water for astronauts. In addition, the lunar rocks also revealed possible significant sources of water beneath the moon's surface (Hananto, 2020).

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Materials on the moon can be used to support continuous exploration from the moon, scientific and economic activities between the earth and the moon (known as cislunar space), or even "exported" to meet Earth's needs. Scientists are still gathering information on the various resources available on the moon. Also, there are many countries that are not just targeting the moon but also asteroids floating in space.

3.2 Legal Aspect of Lunar Mining

Although several landings on the moon have symbolically installed the flags of the Soviet Union and the United States, that does not mean that these countries have claimed ownership of any part of the moon surface. Until now, the international legal status of the ownership of this lunar area was unclear and controversial.

Numerous treaties and agreements address the realm of outer space. The 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, also referred to as the Outer Space Treaty encompasses three core tenets: activities must be conducted for the collective benefit without discrimination, the ownership of celestial bodies is proscribed, and the utilization of outer space must be exclusively for peaceful purposes (United Nations Office for Disarmament Affairs, 1967).

The 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space, commonly known as the Rescue Agreement, designates the launching country as accountable for space endeavors and necessitates immediate communication in the event of accidents; the nation of the accident is responsible for initiating rescue operations (United Nations Office for Outer Space Affairs, 1967).

The 1971 Liability Convention, also known as the Convention on International Liability for Damage Caused by Space Objects, establishes international responsibility for harm caused by space objects, regardless of location (United Nations Office for Outer Space Affairs, 1971). The 1974 Convention on Registration of Objects Launched into Outer Space, often referred to as the Registration Convention, mandates the registration of all launched objects with the United Nations Office for Outer Space Affairs (UNOOSA), specifying details such as the launch country, designer, launch specifics, orbital information, and object function (United Nations Office for Outer Space Affairs, 1974).

The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, commonly referred to as the Moon Treaty, asserts the collective human heritage status of celestial bodies and their resources. However, its effectiveness was limited due to non-ratification by central space-exploring states, including the United States, select European Space Agency members, China, Japan, and India (United Nations, 1979).

In 2018, S. Neil Hosenball, NASA's general advisor and chief US negotiator for the Moon Treaty, suggested postponing lunar mining regulation negotiations under the treaty until the feasibility of moon resource exploitation is confirmed (Beldavs, 2018). In 2015, the 114th US legislative congress passed the Commercial Space Launch Competitiveness Act, allowing US industries and citizens to engage in commercial outer space resource exploitation, excluding resources related to extraterrestrial life. Despite the controversy, the act did not violate the Outer Space Treaty, as it affirmed that the US lacked full ownership rights over outer space objects ("H.R.2262-114th Congress (2015-2016): US Commercial Space Launch Competitiveness Act," 2015). This approach was emulated by countries such as Luxemburg, Japan, China, India, and Russia.

Later in April 2020, lunar mining commenced after US President Donald Trump issued an executive order endorsing it (Wall, 2020). This aligns with the Artemis Program, a NASA initiative undertaken with the European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), and Canadian Space Agency, aimed at establishing a permanent lunar base and enabling human missions to Mars. The Artemis Program encompasses phases including Artemis 1 (2022) involving robots and mannequins, Artemis 2 (2024) with a crew, Artemis 3 (2025) for moon landing, Artemis 4 (2027) constructing a lunar transit station, and subsequent phased landings to fulfill the program's objectives (NASA, 2021).

3.3 The Possibility of Mluku Application in Lunar Mining

The mining of resources on the moon is still being studied, both in terms of technology use and formal legal aspects. Nevertheless, the application of *mluku* in lunar mining can still be offered as a hypothesis. Therefore, in this discussion, three perspectives will be explained, namely *mluku* from the formal legal perspective, *mluku* from the perspective of its application in technology, and *mluku* from a philosophical perspective.

- *Mluku* from formal legal perspective

Based on the Outer Space Treaty of 1967, which was ratified into Law of the Republic of Indonesia No. 16 of 2002, Indonesia cannot use space objects for its own national interests as a sovereign state. However, with reference to the treaty, Indonesia is basically allowed to carry out space exploration subject to international law as long as it is for common interests without discrimination and for peaceful purposes.

Regarding Indonesia's ability to conduct research on outer space objects, this is possible to be done because Indonesia has a dedicated space research agency called *Lembaga Antariksa dan Penerbangan Nasional* (LAPAN). However, so far, there has been no plan by LAPAN itself to create a manned space launch program. The plan for the near future is to utilize a large telescope to observe transient phenomena in the next five years. A transient is an incidental space phenomenon, such as an exploding star, a lunar eclipse, or the transit of an extra-solar system planet in front of its parent star (Warsudi, Budianto, & Mustaqim, 2020).

At least for the forseeable future, *mluku* cannot possibly be carried out on behalf of the sovereignty of the Indonesian state. This is because, first, we are compliant with international law and RI Law No. 16 of 2002. Even if we are to conduct exploration and exploitation of space objects, Indonesia should do it for common interests and not for self-interests. Second, judging from the capabilities of LAPAN itself as the Indonesian space agency, it appears that LAPAN does not yet have any plans to run a space project in the form of exploration or crew

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launch. Based on this, the concept of *mluku* is difficult to realize if it is applied on behalf of the sovereignty of the Indonesian state both for formal legal and technological readiness reasons. Therefore, another solution is that although *mluku* isa local wisdom that emerged from Indonesia, it should first become a local wisdom contributed by Indonesia to the world and be utilized fairly by the country that has a plan to launch a space exploration project in the first place. In this case, *mluku* can be part of a recommendation to the Artemis Program or other programs run by state or non-state entities that are considered to have the capability to carry out space exploration, especially to the moon.

On this basis, the *mluku* concept should be implemented collaboratively between the party who has a lunar mission and the Indonesian representatives who have a comprehensive understanding of the concept. This collaboration is done so that the *mluku* concept can be implemented optimally while still adopting the technology used for lunar mining. Any profit that might be generated from the mining should be treated with reference to the Outer Space Treaty 1967, which states that the profit from exploitation of a celestial body shall not go to a certain country and shall be used for the common good based on the principle of non-discrimination. Indonesia, as the party who contributes the local wisdom, i.e., *mluku*, surely must come to terms that this knowledge is no longer exclusive to itself, but rather, it now belongs to the world. Therefore it will be best to refrain from claiming any profit in honor of the Outer Space Treaty 1967.

- *Mluku* from the perspective of its application in technology

Regarding its practical implementation, *mluku* commonly involves harnessing animals like buffalo, cows, or horses to pull a device named *luku* which is employed for plowing fields. Despite animal power, human operation remains essential through tools called *cethen* or *cemeti*. This approach yields a smoother outcome compared to using tractors. Applying this principle is relatively feasible, as the power of tractors or robots can be calibrated to replicate animal strength, as well as modify the *luku* by retaining key components:

- *Cekelan,* or handle, which means the plow or lunar mining equipment should at least have a part that can be gripped by the driver. In this case, *mluku* on the moon requires a human driver so that the *luku* remains under control.
- *Pancadan* or footing, which means the plow or lunar mining equipment should at least have a footing for a steady foothold so that the *luku* can sink into the soil and turn it over when pulled.
- *Tandhing* or bolt, which means the plow or lunar mining equipment should at least have a joint so that the entire parts are stable and not wobbly, and the *luku* remains stable on the rough surface of the moon.
- *Singkal,* is a unique structure of a traditional plow for stirring and whirling the soil to make it loose. Soil preparation using a plow with a *singkal* shape results in big chunks of soil that clump together. This will be very helpful for stirring clump of soil on the moon under more extreme conditions compared to the earth.
- *Kejen* is the blade of the *singkal* that is made of iron or steel plate, which means the plow or lunar mining equipment should be coupled with a tool sharp enough to excavate minerals, rocks, and other natural resources in general, but smooth enough to prevent overall damage of the surface.

Of all the components maintained in the *mluku* activity, one thing that cannot be assumed by technology is the presence of humans that must remain behind the *luku*. Humans are an essential part of all activities, because all of the sophisticated equipment used for plowing or mining will fail without the human behind it. This part will be discussed further from the philosophical perspective.

- *Mluku from philosophical perspective*

The lunar mining activity is surely not without controversy. Efforts by humans to exploit extraterrestrial resources at least show the nature of humans who will never be satisfied and alwaysask for more. This was the basis of the formulation of the Outer Space Treaty 1967 and Moon Treaty 1979, which certainly has presumed that certain superpower countries have aimed to exploit space for their own commercial interests. Some superpower countries were then proven to have "circumvented"the treaties by making their own regulations related to the launch of space imssions by disavowing state involvement, as was done by the United States in the Commercial Space Launch Competitiveness Act of 2015. This shows that the lunar mining effort, backed by the executive order from Donald Trump in 2020 and the Artemis Program run by NASA and some other parties over the next few years, is something inevitable. In other words, the ambition to exploit and commercialize space resources is something unstoppable.

What can be done instead is limitation, so that the exploitation and commercialization are not greedy, excessive, and aimed only at the interests of one or a handful of groups. However, limitation through legal measures has been proven ineffective because the superpowers, in particular, always have a wayto bypass the law, including international law. Therefore, the viable limitation is through the philosophical aspect, which is offered by this *mluku* activity. In other words, *mluku* is not only about the technical aspect of the technology, but also about the philosophy that can be adopted so that lunar mining is not only about effectiveness and efficiency but also about the benefits for the whole of humanity, both human and nature, on earth or beyond earth.

With regard to the components existing in the *luku* that have been mentioned in the previous part, their use is not without reason, because they contain local wisdom as follows:

- *Cekelan,* or handle, philosophically means that in carrying out lunar mining, humans should adhere to the transcendent laws of nature and immanent (man-made) international laws.
- *Pancadan,* or footing, philosophically means that, in carrying out lunar mining, humans should rest on the principle of justice and benefits for all humanity in a non-discriminative manner.
- *Tandhing,* or bolt, originates from the term *nandhingke,* or comparing, philosophically means that in carrying out lunar mining, humans should be able to compare the

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conditions of the past, present, and future, so that their activities are not oriented to the present only without observing future interests of humans and nature.

- *Singkal*, which is a unique structure of a traditional plow for stirring and whirling the soil to make it loose, originates from the term *sing sugih akal*, which more or less means "responsive" and "quick-witted". In lunar mining that is certain to run into many obstacles, humans should continue to find solutions and be responsive to various problems without giving up.
- *Kejen*, is the blade of the *singkal* that is made of iron or steel plate originates from the term *ka-ijen* or "the one". Although this term tends to refer to a monotheistic idea, in this context we can assume that "the one" is the principle of harmony between humans and nature, that cannot be sacrificed for the interests of one or a handful of groups only.

3.4 Mluku Usage Model for Lunar Mining

Based on the explanation on possible *mluku* application in lunar mining, a hypothetical model is formulated as shown in Figure 1:

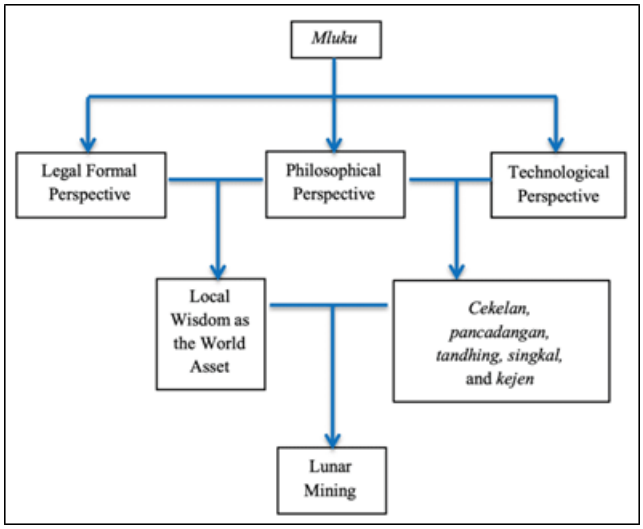

Fig. 1. Hypothetical Model of *Mluku* Usage for Lunar Mining

Expanding upon the preceding model, a more comprehensive explanation emerges as follows: The *mluku* activity, which is referred to as a local wisdom in the rice field plowing system in Indonesia, becomes a conceptual offering for the lunar mining activity that will be carried out by a number of state and non-state entities over the next few years. This possible offering will be divided into three perspectives, namely the formal legal perspective, the philosophical perspective, and the technological perspective. From the formal legal perspective, which intersects with the philosophical perspective, *mluku* is only possible if the concept of *mluku* itself is considered as belonging to the world, due to its impossibility to be implemented as a concept that is owned by Indonesia as a sovereign country. Meanwhile, from the technological perspective, which also intersects with the philosophical perspective, *mluku* has five important components to be maintained, although with modifications, namely *cekelan*, *pancadhan*, *tandhing*, *singkal*, and *kejen*. These five components have their own philosophy, which can show certain wisdom in viewing the relationship between humans and nature. With these perspectives as a whole, *mluku* can make a contribution to the lunar mining activity.

IV. Discussion

Several key conclusions can be drawn in light of the exploration into the potential integration of *mluku* in lunar mining endeavors. First, from a formal legal standpoint, *mluku* cannot be directly attributed to the Indonesian state's sovereignty due to adherence to the Outer Space Treaty of 1967 and the absence of immediate space mission plans from LAPAN. Instead, *mluku* could function as a shared global wisdom, recommended for programs such as the Artemis Program or undertaken by entities with the capacity for lunar exploration. Second, on a technological level, employing animals like buffalo, cows, or horses, as in *mluku*, is impractical for lunar mining due to size constraints, cost, and untested viability. Instead, substituting comparable power through technology like tractors or robots is a practical solution. Retaining fundamental *mluku* components—*cekelan*, *pancadhan*, *tandhing*, *singkal*, and *kejen*—while adapting them to lunar mining needs is vital. Lastly, from a philosophical perspective, *mluku* instills a lunar mining philosophy that calls for alignment with both natural and human-made laws, equitable justice, global benefits without discrimination, foresight, unwavering problem-solving, and harmonious coexistence between humanity and nature—a principle that transcends self-interest for collective well-being.

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