Author
C. Jimenez Monroy

TOWARDS A LEGAL FRAMEWORK FOR SUSTAINABLE DEVELOPMENT ON THE MOON: THE CASE OF IN-SITU RESOURCE UTILIZATION.

ABSTRACT

Many experts agree that In- Situ Resource Utilization (ISRU) is necessary to support the long term scientific missions on the Moon from economic and technological perspectives. This brings up a series of important questions: should we determine a limit for ISRU activities? What could be the legal justification for such a limitation? Which authority would be in charge?

ISRU on the Moon is the key to help with two main problems of long term missions: First, the reduction of the mass and cost of transportation with the production of propellant from natural resources on the Moon: Oxygen, Hydrogen (Atomic hydrogen). Secondly, ISRU provides the option of self-sufficiency and safety for missions with the production of elements required for life support systems to assure the daily crew needs (such as oxygen: 0.84 kg and water :2.28 kg per crew member).

The International Legal Framework for ISRU has two principal instruments: The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and other Celestial Bodies and the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies. The latter is one of the most controversial of the United Nations Treaties because it deals with the exploitation of natural resources and some countries found its language deficient with vague concepts and "anti-developmental" approaches to space resources. – Spacefaring nations have not ratified the Moon Agreement-

The analysis of these two documents cover the following aspects: Freedom of Use and Exploration of Outer Space, Exploration of Outer Space for the benefit of all Mankind, Outer Space as Common Heritage of Mankind, sovereignty over Celestial Bodies, the duty to avoid harmful contamination of Celestial Bodies and to inform UN about the activities concerned with the exploration and use of the Moon.

A proposal for Sustainable Development (SD) on the Moon should include an analysis of the consequences of present actions and the effects on future public and environmental health. Such an analysis should be interdisciplinary, and focus on the environmental, economic and social concerns for the preservation of the environment and social well being.

SD considers the economy as a very important field of sustainability. Hence, SD is not against the lunar economy or the use of ISRU. This model invites the decision makers to consider not only the economy issues but also the environmental and social aspects to design a suitable model for long term use of ISRU by considering the Moon environment – geologically dead, airless, lifeless- and the rights of the future generations, as a subject of law recognized by Space Law and Environmental Law.

The proposal for SD of ISRU on the Moon identifies the necessary guidelines for the International Regime on the Moon.

1. INTRODUCTION

Specific policy and regulation for ISRU on the Moon shall consider space exploration targets. The limit of ISRU activities and its guidelines for the different scenarios could improve the efficiency in the use of space resources. Decision maker's shall consider a cost-effectiveness analysis, taking into account the environmental and health costs (astronauts and the Moon) of technological options.

The present document implies a basic knowledge of basic concepts to understand the legal approach to space exploration, for that reason the first part deals with the explanation of necessary concepts with regard to space exploration.

The second part is the analysis of SD and how can be applied this model to IRSU on the Moon.

The third part of this paper is the legal regime of ISRU and planetary protection.

The last part handles the conclusions and specific recommendations to implement SD for ISRU on the Moon.

1.1 In- Situ Resource Utilization ("ISRU")

This term has been defined as "living of the land" (ESA, 2001).

The National Aeronautics and Space Administration (NASA) through the Study on Capability Road Maps which was develop according with NASA's objectives, set that ISRU is "…harness and utilize space resources to create products and services which enable and significantly reduce the mass cost and risk of near term and long term exploration".

To explore the Solar System, any product from indigenous materials that significantly reduces mass, cost and risk should be considered, such as oxygen, hydrogen and water. The high upload mass requirements and today's launch capability means that ISRU is a prerequisite for missions beyond the Moon to produce indigenous propellants –methane, oxygen and carbon monoxide-.

1.1.1 Advantages of ISRU for space exploration.

- Allows sustainable human presence beyond Low Earth Orbit for long term missions.
- Reduce the cost of space missions.
- Reduce risk to face emergencies during the mission as a part of interrelationships among lunar base subsystems, such as transportation.
- Assist in further human exploration and create self-sustaining and adaptable colonies on the Moon and beyond, such as Mars.

1.1.2 Main areas of space exploration to apply ISRU

As we can see from the advantages described above, it is possible to identify two main areas, which would benefit from ISRU:

1. Life support- ISRU life support consumables directly needed are water, oxygen and nitrogen.
The crew aspects of exploration must be to a large extent and self-sufficient, and shall include the follow elements:
A) Life support consumables (oxygen, water, food) must be recycled.
B) Biohazards and chemical contamination must be controlled.
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D) Biohazards and chemical contamination must be controlled.

2. Propellant production. The preferred propellants are cryogenic oxygen and cryogenic methanes in the ratio (ESA, 2001). ISRU helps with the production of propellants and reactants for fuels cells. These are the basic elements needed to ensure the safe return to Earth with the provision of fuel for the crew vehicle to ensure the possibility of fast return to Earth when something goes wrong.

In particular, oxygen, which is considerably heavier than hydrogen, is costly to transport from Earth to the point of use in space. However, in the Moon oxygen is much more abundant than hydrogen in lunar rocks.

1.2 Moon principal characteristics.

Three principal characteristics of the Moon (Wikipedia, 2006):

- The Moon's crust is blanketed of dusty outer rock layer called regolight. The regoligh is the result of rocks shattered by billions of year impacts. The crust ranges from 60 km on the near side to 100 km on the far side. The regolight varies from 3 to 5 m in the maria to 10 to 20 m in the highlands.
- Moon has been geologically dead for around three billion years, and has no atmosphere shape its surface. Any changes to its features have been made by outside forces, mainly the impact of meteors (Tumilson, 2005).
- Clementine orbiter also indicate that there maybe long-frozen deposits of ice under the shadows of some polar craters. The presence of usable quantities of water on the Moon would be an important factor in rendering lunar habitation cost-effective, since transporting water (or hydrogen and oxygen) from Earth would be very expensive.

1.2.1 Natural resources on the Moon

- Oxygen. A current assumption is that oxygen would be the most valuable product (Burt, 1989). The Lunar regolight has been studied since the Apollo missions. Available information demonstrates that the process to produce oxygen on the Moon would need a specific technique because without a lunar atmosphere, oxygen has to be produced from oxygen-rich minerals. More than 20, mostly non-terrestrial, physico-chemical processes have been identified to produce oxygen from the solid lunar regolight, all requiring the build-up of an extensive chemical factory.

Demand for huge amounts of energy to be able of recover the oxygen from ilmenite has led NASA's dreamers to think about the option of a nuclear power project for the oxygen plant. However, it will be very difficult to justify building a large nuclear power plan on the Moon for the oxygen extraction (Herkenhoff, 1989).

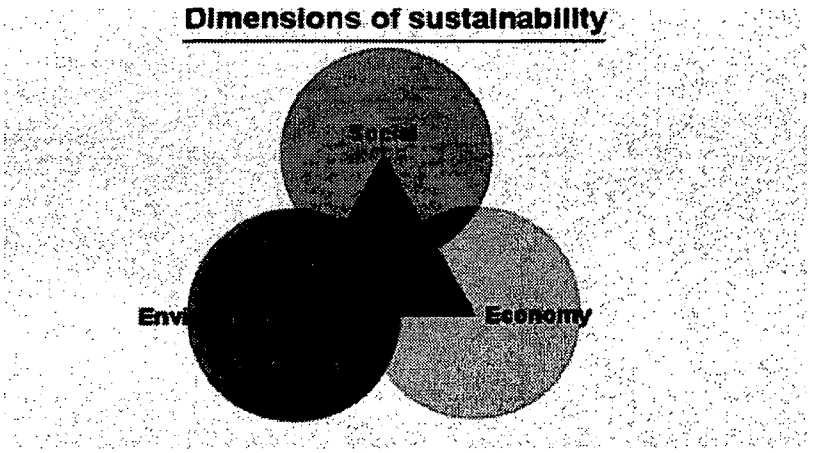
- Hydrogen. Important element of water or reactants on the Sabatier process, if not indigenously available, inevitably has to be recycled and (re) supplied from Earth. If cryogenic hydrogen is carried, the extremely long mission duration imposes special constraints in order to minimize the hydrogen boil-off.
  Finding concentrations of water at the lunar poles or extracting the dispersed solar wind derived hydrogen in the lunar regolight would gently improve the economics of the transportation system.

1.3 Sustainable Development

Sustainable Development tries to improve human's productivity without damaging or undermining society or the environment. This development proposes a progressive socio-economic advance without growing beyond the ecological carrying capacity for natural resource regeneration and waste absorption.

Moreover, this model of development takes into account for any decision the possible consequences of the currently actions on future public and environmental health through previous interdisciplinary analysis of environmental, economic and social concerns for the preservation of the environment, social well-being and security of the entire world.

The follow model resumes SD on three dimensions and shows the continuous interaction among the different elements: environmental (conservations), economic (growth) and social (equity) dimensions (Flint, 2004).



1.3.1 Sustainable development on the Moon

Economy. The analysis of cost-benefit considering environment and economic issues in the management of ISRU on the Moon shall include this information in the final decision:

- The study of the special environmental and developmental characteristics of the Moon, producing profiles and inventories of environmental resources.
- The development of techniques for determining and monitoring the carrying capacity of the Moon under different development assumption and resource constraints.
- The preparation of medium-and long-term plans for sustainable development. The integration of environmental consideration with economic and sector planning and policies.
- The adoption of Moon area management techniques, such as planning and environmental impact assessments, using Geographical Information Systems (GIS).
- The implementation of sustainable development plans.
- Bases on precautionary and anticipatory approaches, the design and implementation of rational response strategies to address the environmental, social and economic impacts of environmental change, and the preparation of appropriate contingency plans.
  Precautionary strategies are related with air pollution, water pollution, waste management and natural resource management.

Environment. The main concern in planetary protection policy is how to protect the extraterrestrial life against contamination and back-contamination. Otherwise, there were almost no interest in the preservation of the existing lifeless surfaces of extraterrestrial bodies as the Moon, although some planetary transformation plans were made public a long time ago (Almar, 2002).

Moon environment are practically unchanged since ages and damage caused by any human intervention would be irreversible, this is a problem for ISRU, but can be justify for survival reasons in a limited way to control the human disturbance activities and contamination.

From the scientific point of view, a limited, well-defined initiative has to be done to select scientific investigation areas and objects of highest priority on different celestial bodies.

The last, sentence is according with the suggestion of Tennen (2002), who provides two approaches on planetary protection policy:

1. The creation of the category of target bodies which are of interest for biological or chemical evolution, but which are considered to present only a remote chance that contamination could jeopardize future exploration.
2. The establishment of "special regions" where it is believed water may be present.

An option to incorporate planetary environment in space activities is through the Environmental Impact Assessment for Space Activities which could be included for the decision maker's. This is probably the best example of one approach that integrates economic, social and environmental considerations (Viikary, 2002).

Social. From this point the view the problem is the different levels of development among the countries on the use of outer space. However, the astronauts as envoys of humankind can be considered as subjects who represent equity benefits of space activities as a right of all humankind on the basis of common heritage.

2. LEGAL REGIME

ISRU on the Moon has two main international instruments to consider. First, the Treaty on Principles governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies called the Outer Space Treaty (United nations, 1967). The second main international instrument is the Agreement governing the Activities of States on the Moon and Other Celestial Bodies, also known as the Moon Agreement (United Nations, 1979).

The Moon Agreement has not been ratified by any of the main spacefaring nations for that reason most of the countries consider is not effective under international law (Oosterlinck, 1996). The importance of this document is because it was the first legal attempt to deal with exploitation of natural resources on the Moon, which is directly related with ISRU.

For many years the Moon Agreement has been object of revision by the Legal subcommittee of the Commission of Peaceful Uses of Outer Space. Most of the space faring Nations argues a deficient language, vague concepts and anti-developmental approaches to space resources (Harris, 1996). Some countries talk about four instead of five Treaties of the United Nations for Outer Space.

However, some authors consider that the Moon Agreement is not needed for further development of lunar resources, because the Outer space Treaty provides the legal framework for the use of lunar resources (Schmitt, 1998).

I agree that the main principles to use space resources are provided by the Outer Space Treaty, hence the specific practice of ISRU has a recognized international framework. For that reason, although most of the countries have not ratified the Moon Agreement, it doesn't mean countries have not limits or any regulation to follow in the use of space resources.

2.1 Common Heritage of Mankind

The Moon Agreement dealt for the first time with the exploitation of natural resources. Article 11.1 refers to the Moon and its natural resources as "Common Heritage of Mankind" (Schmitt, 1998).

The concept of Common Heritage of Mankind as used in the Outer Space Treaty is considered as unique and its interpretation and independent of the concept defined by the wording in the Treaty of the High Seas as res communis (Oosterlinck, 1996). The Law of the Sea expands on the Common Heritage of Mankind doctrine and goes further to

mandate an International Seabed Authority. Now the Law of the Sea may serve as a model for Space Law (Clayton, 1999).

Apart from this understanding, Oosterlinck believes that as far as the exploitation of mineral resources is concerned, the similarity is striking between space law and the law of the High Seas and Antarctica.

The interstellar space would be similar to the sea and the celestial bodies to res nullius (Oosterlinck, 1996).

The Moon Agreement incorporates the Common Heritage of Mankind principle, and for this reason the spacefaring nations are reluctant to ratify it because there are resources on the Moon that may have significant economic value sometime in the future and nations would eventually be pressured by their firms to withhold signing away valuable rights (Hertzfeld, 2005).

An extension of the benefits to all mankind principle is the Common Heritage of Mankind. The idea is that all nations should benefit from the knowledge and technology and profits generated by using resources in outer space. This provision is advocated by nations that do not currently have the ability to access these resources on their own, but with the idea of Mankind richer nations would share the benefits with all the other nations. This is a controversial point because commercial interests do not support this since it means the sharing of proprietary technology as well as reducing potential profits (Hertzfeld, 2005).

2.2 International Regime of outer space

Article 11.7 of the Moon Agreement states the international regime for the Moon. Concentrating on an international order in the freedom of the use of Outer Space for the benefit of all countries, States party to the Agreement shall assume to establish an international regime including the appropriate procedures to govern the exploitation of the natural resources of the Moon.

According to this article, the main purposes of the international regime to be established shall include:
- The orderly and safe development of the natural resources of the Moon
- The rational management of those resources
- The expansion of opportunities in the use of those resources
- An equitable sharing by all States party in the benefits derived from those resources

Considering these key issues, all activities with respect to the natural resources of the Moon shall be in accordance with the purposes adopted in the international regime.

Schmitt considers that the international regime would complicate private commercial efforts and give other countries political control over the permissibility, timing and management of all private commercial activities (Schmitt, 1998).

States, Mankind, Future Generations as Subjects of Space Law and the Future of Enterprises. Other legal topics related with ISRU that must be addressed concern the present increase of interest of private companies in space activities. One of the topics is the definition of subjects of Space Law.

Currently, States are responsible for their national space activities. According to Article VI of the Outer Space Treaty, States Party to the Treaty are internationally responsible for their national activities in outer space, including on the Moon and Mars. Such activities are historically carried on by governmental agencies or by non-governmental entities. At the beginning of the Space Era only States were interested in space projects, but now there are many space companies that are interested to invest and develop space projects.

Intergovernmental Organizations can also be subjects of Space Law but not private commercial companies, which have become the new players to support the commercialization of space activities in specific areas.

Article 4 of the Moon Agreement stated that the exploration of the Moon and other celestial bodies shall be considered as a province of all "Mankind", so we can consider Mankind as a subject of Space Law. The problem with the concept of Mankind as a subject of International Space Law is that Mankind does not have any authority to represent and defend its interests in Outer Space.

Moreover, this Article also refers to the future generations as new a subject of law, that are not well defined but the term is commonly used in the environmental law related with sustainable development issues. This article deals with issues that have to be considered to generalize the legal framework of space exploration and for ISRU. Such subjects as the sustainable exploitation of the Moon resources and other celestial bodies as Mars, mean the long term planning has to be sure that future generations will have the opportunity to use the resources from other celestial bodies for its development.

2.3 International Law and outer space

The extension of international law to outer space has been gradual and evolutionary, commencing with the study of questions relating to legal aspects, and then proceeding to the formulations of a legal nature.

Article III of the Outer Space Treaty specifies that the activities in the exploration and use of the Moon and other celestial bodies shall go on in accordance with international law, including the Charter of the United Nations. Moreover, Article II of the Moon Agreement indicates that all activities on the Moon shall be carried out in accordance with international law.

When no direct references exist in the UN Treaties it is possible to check International Law to find references applicable to the subject; for instance, the protection of the Common Heritage of Humankind: such a concept was not foreseen in the 1967, until it was included into the Moon Agreement in 1979. However, this concept was defined before in the UN agreement on the Law of the Seas in 1982, and signed by the US in 1995, under the rules of the treaty. These proceedings would also be applicable to space law (Harris, 1996).

2.4 Protection of Interplanetary Environment

Planetary environments change very little over time, and therefore any damage caused by human interaction would be irreversible. Almar classifies the activities on celestial bodies linking the consequences as follows:

- Research: In Situ Research produces some kind of pollution.

• Industrial activity: mining in particular, destroys smaller bodies. If mankind decides to mine the Moon or colonize Mars, the environmental impact will increase by at least an order of magnitude.
• Colonization and terraforming: the result is a large-scale transformation of the environment to accommodate human life.
• Free for all: whoever gets there first should have the right to do whatever they want with the materials they find (Almar, 1999).

At present, in accordance with the UN Treaties, the protection of the environment of the Moon and Mars and other celestial bodies is a duty of all the States involved in the space exploration activities.

Therefore, the next regulations shall be followed:
Article IX of the Outer Space Treaty declares that States shall conduct exploration of the Moon and the other celestial bodies in such a manner so as to avoid their harmful contamination and also adverse changes in the environment of the Earth, resulting from the introduction of extraterrestrial matter and when necessary, adopt appropriate measures for this purpose.

With this respect, the phrase "harmful contamination" is not clear and it can be open to interpretation and argument in the context of the Treaty, that it means harmful to humans rather than harmful to the environment. Some space activities will not immediately be harmful to humans, but it could prove extremely harmful to science.

Article IX of the Outer Space Treaty is well intentioned, but avoids the definitions of "harmful" (Williamson, 1997). The Outer Space Treaty provides insufficient protection for the space environment. in particular for the protection of the planetary bodies from the creation of further debris, which will undoubtedly accompany future development exploitation.

Article 7.1 of the Moon Agreement states that in the exploration and use of the Moon, States party shall take measures to prevent disruption of the existing environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extraenvironmental matter or otherwise.

In Article 7.3 of the Moon Agreement, it is suggested that consideration be given to the designation of areas of special scientific interest, or international scientific preserves, which, it states, would require agreement in consultation with the competent bodies of the UN. This is not an end in itself because of the need for further consultation, but suitably extended to include other celestial bodies, would make a useful addition to Outer Space Treaty (Williamson, 1997).

Finally, regarding extraterrestrial exploration missions, the Committee of Space Research (COSPAR) has established Planetary Protection recommendations in order to protect the environment of celestial bodies from biological contamination by terrestrial microorganisms. According to these recommendations, projects involved in planetary exploration programs include in their development plans specifications for biological cleanliness.

COSPAR recommendations includes sterilization, biocleanings and planetary landers integration in sterile environment in order to ensure Mars environment protection (Debus et al, 1997).

3. CONCLUSIONS

Sustainable Development for ISRU on the Moon:

1. Policies, plans, and activities that improve equality of access and quality of life for all. This point is specially controversial because as we know space activities are carry out only for space fairing nations, not all the countries are participating as an actors in space activities so it is hard to imagine an scenario where all the countries has access to the ISRU as the SD states.
2. Recognizes the limits and boundaries beyond which the Moon environment behavior might change in unanticipated ways.
3. Challenges us to look to the future, and to fully asses and understand the implications of the decisions made today on the lives and livelihoods of future generations and the natural environment of the Moon.

Goals that lead to sustainability:

- Provide safe and equal access to Moon resources
- Measure and protect against environmental degradation on the Moon
- Reduce discharges of pollutants into surface and ground
- Prevent human health risk due to spread of waste diseases, water contamination and hostile e actions.
- Prevent physical modifications from land use / cover changes or disturbances with Moon surface that cause risks to humans, natural systems. The important point here is that it is not possible to refer on the Moon property rights to protect and justify the exploitation.
- Encourage a holistic approach to evaluating all Moon resources issues that is participatory, equitable and socioeconomically sensitive.
- Develop appropriate Moon resources policies; institutional arrangements and structures; financial systems; and legal and regulatory authorities to achieve integrated Moon Resources Management.

For a long term and in ideal scenario, Sustainable Development can be designed with more precision if the follow information would be collected:

A. Strategic → Possible decision: Intensive exploration for mineral resources→ Information required: current reserves of resources, rate of consumption (present and future), projected need of resources.
B. Tactical → Possible decision: develop exploration → Information required: Potential reserves, probable reserves and in-shelf deposits, economics of exploration.
C. Technical → Possible decision: detailed estimates of reserves → Information required: structural data, lithological data, geochemical data, geophysical data, borehole data.

Sustainable Development on the Moon proposal.
It is necessary to develop an international legal framework in order to establish rules for environmental protection of Planets, such as the Moon. The technical and specific rules

could be included on the base of ISO standards format but for space activities. Moreover, it is necessary to set the Authority in charge for monitoring and enforcement the rules for space activities according with planetary protection, and provide the legal options to appeal by the Countries.

ISRU is necessary for space exploration, but also is absolutely necessary have a clear rules for ISRU in order to prevent situations such as the environmental problems on the Earth and the Space Debris on outer space.

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