

An International Lunar Resource Prospecting Campaign. C. R. Neal¹ and A. Abbud-Madrid², ¹Dept. of Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, USA (cneal@nd.edu); ²Director, Center for Space Resources, Colorado School of Mines, Golden, CO 80401, USA (aabbudma@mines.edu).

Introduction: Lunar resources that could be useful for sustaining humans on the Moon (and potentially for export off-Moon) have been known to exist for years. However, understanding them and their use in enabling science, human exploration, and a vibrant cislunar economy remains rudimentary at best. We define the critical next step for understanding lunar resources that could build science, exploration, and commercial synergies.

Resources vs. Reserves: This semantic yet critical distinction is crucial in understanding the full scientific, exploration, and commercial potential of lunar resources. The USGS [1] defines resources and reserves as follows: **Resource:** a concentration of naturally occurring solid, liquid, or gaseous materials in or on the crust in such form that economic extraction of a commodity is regarded as feasible. **Reserve:** That portion of an identified resource from which a usable mineral or energy commodity can be *economically and legally* extracted at the time of determination.

The term “resource” in a lunar context has been used interchangeably with “reserve”, which has caused confusion. Based upon current knowledge and likely users, the only potential lunar reserve is oxygen from regolith as it is present in about the same proportion anywhere on the Moon. However, defining it as a “reserve” requires the economic and legal issues to be addressed.

Economics: The reserve definition implies that the resource can be extracted, refined, transported, and used at a profit (i.e., the value of the products is more than the cost of acquiring the products). This has not been achieved for any lunar resource because only the United Launch Alliance has placed a value on lunar-derived water (for rocket fuel) at \$500/kg [2,3]. At this time, a true market value for any lunar resources has not been established so their economic potential cannot be evaluated.

Legal Implications: The Outer Space Treaty (OST) [4] has been interpreted to indicate use of lunar resources is prohibited or severely restricted. For example, **Article I** states: “*The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries*”. **Article II** further states: *Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.* However, **Article III** states: “*States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies..., in the interest of maintaining international peace and security and promoting international co-operation and understanding*”. An International Lunar Resource Prospecting Campaign would therefore be compliant with the Outer Space Treaty.

The Artemis Accords [5] establishes a common vision via a set of principles/guidelines/best practices for the governance of civil exploration/use of outer space to advance the Artemis Program. Space resources are highlighted where the signatories:

- *note that the utilization of space resources can benefit human kind by providing critical support for safe & sustainable operations;*

- *emphasize that extraction & utilization of space resources be executed to comply with the OST & in support of safe & sustainable space activities;*
- *commit to informing the Secretary-General of the United Nations as well as the public and the international scientific community of their space resource extraction activities in accordance with the OST;*
- *intend to use their experience under the Accords to contribute to multilateral efforts to further develop international practices and rules applicable to the extraction and utilization of space resources, including through ongoing efforts at the COPUOS.*

An International Lunar Resource Prospecting Campaign (ILRPC): An ILRPC is needed to understand the full economic potential of the Moon and comply with [4]. This has begun in an ad hoc fashion with the ISECG member missions to the lunar south pole to explore volatile deposits [6], but extensive cooperation between nations is lacking. This could be initiated either by the Artemis Accords or the ISECG, building on the work of LEAG [6]. Encouraging such international collaboration in lunar prospecting, international diplomacy is promoted. History shows us that international cooperation in space leads to an enduring program (e.g., ISS), whereas competition does not (e.g., Apollo). An ILRPC allows countries to participate in this exploration, regardless of economic status. Countries could contribute instruments, launch vehicles, rovers, etc., to ensure the same datasets are obtained for each site identified by orbital data (e.g., [7]). By sharing data obtained from this campaign (which will inform science, exploration, and commerce), commercial companies (& space agencies) will understand the reserve potential of lunar resources, such that a true market value can be determined and the reserve potential fully evaluated into the future.

Such an approach requires organization, integration, and coordination at the highest level. The current organization of Artemis is through mission directorate cooperation via a federated board. If this model is used, the integration needed for the ILRPC campaign will be subject to the traditional inefficiencies of stove-piping that is endemic at NASA. Therefore, **Artemis** needs to become a **Program** and have a position above the directorates at the Administrator/Deputy Administrator level to avoid stagnation. The **Artemis Program** will require a leader who can integrate the relevant pieces from the mission directorates, thus avoiding any “turf wars”. Establishing the ILRPC through the Artemis Program office would encourage international partners to team with NASA, maybe through the Artemis Accords or other avenues, but international and commercial on-ramps to the ILRPC should be built in from the beginning. This approach would allow lunar resources to be, for the first time, considered as essential for establishing a permanent human presence on the Moon and kick-starting the cislunar economy that would benefit society here on Earth.

References: [1] USGS. (1980) *Geological Survey Circular 831*. [2] Sowers G. (2016) *Space Policy* 37, 103-109. [3] Sowers G. (2018) *Space Journal* #3(17), 8-13. [4] United Nations (1966) *Outer Space Treaty*. [5] NASA (2020) *The Artemis Accords*. [6] [LEAG-ISECG Volatiles SAT 2 Report](#) (2017). [7] [LEAG \(2015\) Volatiles SAT Report](#).