

## **Opening The Moon for Business**

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We are entering a new phase of space activity – call it MOON 2.0 – when humans go back to the Moon after 50 years of absence. But this time it will be very different. This will be the age of Lunar Commerce and Infrastructure.

### **Why do we want to go back?**

There are a number of reasons why humans are planning to return to the surface of the Moon for permanent and peaceful purposes, including science, resource extraction, space tourism and other governmental and commercial endeavors. The Moon has a surface area of about 15 million square miles, which represents approximately the same coverage as the continent of Asia does on Earth. So, there is plenty of room for further exploration, and eventual exploitation, and there will be an associated need for habitation and other infrastructures. And regulation.

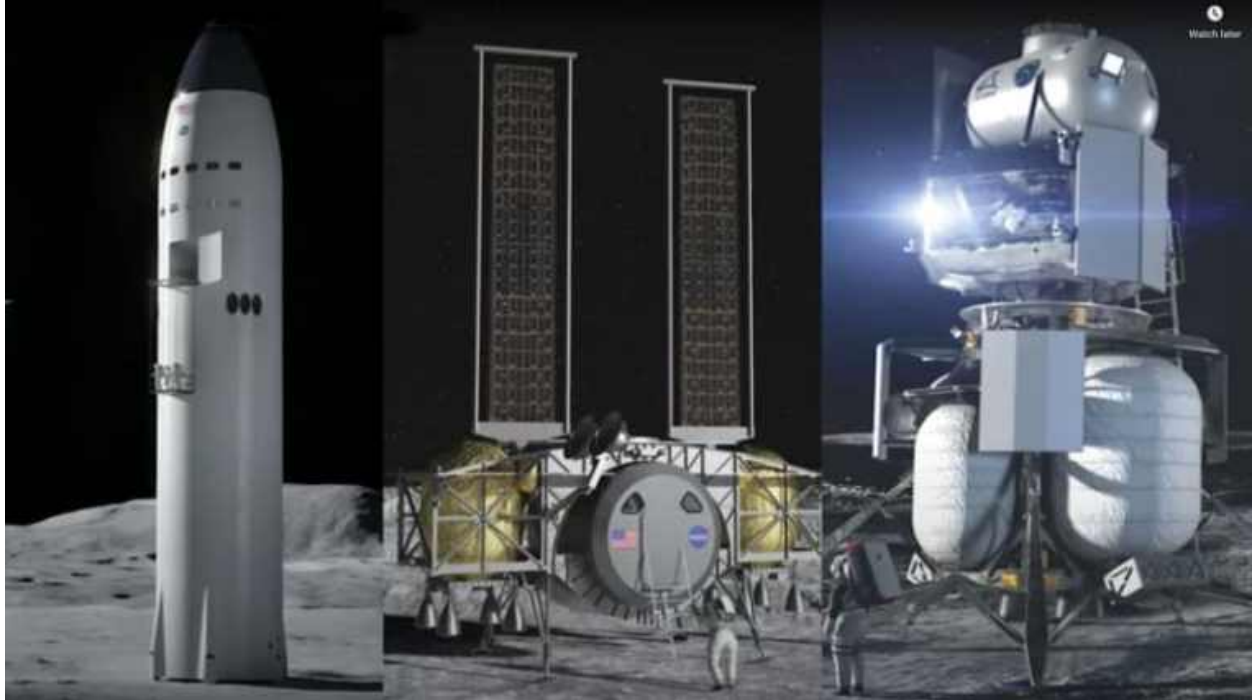
### **Plans for the 2024 Return to the Moon**

In the US, there is a two-pronged approach to returning to the Moon: NASA is pursuing EO 13914, *The Executive Order on Encouraging International Support for the Recovery and Use of Space Resources* (6<sup>th</sup> April, 2020) in conjunction with the Administration's Artemis program plans to place humans back on the Moon by 2024. In the case of the 2024 return logistics, the chosen approach will take advantage of available commercial technologies, and has begun with contracts announced May 31<sup>st</sup>, 2019 for precursor robotic landers, as shown below. The landers shown, with their respective NASA contract awards, are the Astrobotic Peregrine (\$79.5M), The Intuitive Machines Nova-C (\$77M), and the Orbit Beyond/Indus lander and rover (\$97M). The Astrobotic and Orbit Beyond landers were originally entries to the Google Lunar XPRIZE Competition (GLXP), which had offered \$40M in prizes for any non-governmental team to land on the Moon, travel for 500m and then send back high definition pictures, but which ended without a winner in 2018. However, The Orbit Beyond lander, which was based on the Team Indus GLXP craft designed and built in Bangalore, India, has now been withdrawn from the program because of a requirement for the manufacturing and assembly to be performed in the US.



Robotic pre-cursor landers forming part of NASA's Artemis Program – the Commercial Lunar Payload Services (CLPS) - aimed at supporting a crewed lunar landing by 2024.

And these robotic lander contracts were followed by announced awards on April 30<sup>th</sup>, 2020 for initial studies of crewed lander concepts, by the three teams as shown below. They represent three very different architectures for achieving the landing. The SpaceX and Dynetics vehicles use the same engines for landing and take-off, whereas the Blue Origin approach follows the Apollo precedent with separate engines for landing and leaving. The ultimate decision on the preferred approach will not be made until the end of the assessment period after ten months. Furthermore, the choice of lander design is linked with the choice of launch vehicle capable of doing the job and doing it by the 2024 schedule date.



Three commercial crewed lander concepts, with associated NASA contract awards, as proposed by SpaceX (\$135M), Dynetics (\$253M), and Blue Origin/Lockheed Martin/Northrop Grumman (\$579M).

While these architectural decisions are being made, the ground rules for future Lunar commerce and infrastructures are also being written right now. The idea is for this time to achieve sustainable presence for long duration missions.

### **What makes Moon business possible?**

Apart from the technological steps, described above, there have also been a series of concurrent regulatory initiatives and developments, some of them interconnected, both domestic US and international, that aim at authorizing commercial business on the Moon:

#### *Artemis Accords*

These Heads of Agreement were announced on May 15<sup>th</sup>, 2020. They were developed by NASA and are intended to form some common language in any bi-lateral contracts between NASA and any partners, domestic or international, in the joint approach to achieving the Artemis objectives of landing humans back on the Moon by 2024. They are to some degree an amplification, and further interpretation, of some aspects of the Outer Space Treaty of 1967. They reiterate the need for interoperability, emergency assistance, and specifically cite the need for protecting Lunar heritage sites. They introduce the idea of “safety zones” and “de-confliction of activities” requiring a new focus on “Registration” to avoid harmful interference. Also, they reinforce the US position that Lunar resource extraction and utilization is provided for under the auspices of the Outer Space Treaty.

*The Hague Group*, or to give it its full name *The Hague International Space Resources Governance Working Group*, was established in January 2016 trying to establish an effective, enforceable and universal legal framework to manage and protect humankind's common heritage in outer space. The group released (12<sup>th</sup> November, 2019) a set of *19 Draft Building Blocks for the Development of an International Framework on Space Resources Activities*, and they are intended to assemble the areas to be decided in international law as an era of space mining approaches. The Building Blocks include recommendations on responsibilities, access to, and utilization of space resource activities, including avoidance of harmful impacts. They embrace the idea of safety zones (including around Heritage Sites), benefit sharing, registration, and liabilities.

*ForAllMoonkind* is a NGO which has observer status at the UNCOPUOS, and has concentrated its efforts on assuring the protection of Lunar legacy sites. This non-profit has achieved a great deal in its short lifetime (it was created in 2017). In terms of US Law, the tenets of the protections advocated by *ForAllMoonkind* are now ensconced within the Artemis Accords. With regards to international agreements, the main provisions have now also been accepted within the regulatory language being proposed by both *The Hague Group* and the *Moon Village Association (MVA)*. Furthermore, *ForAllMoonkind* has already put in place a Registry of all lunar heritage sites (from all nations) and peopled it with a wide array of relevant data. This Registry may therefore become a good starting point for the broader Registry required by the developing regulations, both domestic and international.



At the UN Committee for the Peaceful Uses of Outer Space (UNCOPUOS) in Vienna, 17<sup>th</sup> June, 2019, with delegates considering the proposal from the observer status NGO ForAllMoonkind for protecting the lunar legacy sites.

*The Moon Village Association (MVA)* is an NGO that has been established (in 2017 In Vienna Austria) to undertake addressing these issues associated with mankind's relatively imminent return to the Lunar surface for a mixture of governmental, commercial and private purposes. The MVA is making progress in addressing the interrelated issues by way of a series of Working Groups, and has the status of a Permanent Observer at the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) in Vienna, Austria. Active working groups of the MVA include the Architectural Concepts W.G., Coordination and Cooperation W.G., and Cultural Considerations W.G. The focus of the work is on

getting international acceptance of the Moon Village Principles (MVP), which are in agreement with, but offer wider scope than, the US/NASA Artemis Accords.

*Lunar Development Cooperative*, LDC, is a proposal from a number of authors with a National Space Society background (although it is not an NSS-endorsed initiative). The idea is to create something like a combination of a Port Authority and a Hudson's Bay Company, established via a shareholders' agreement, which would provide a range of Lunar infrastructure and service offerings at sites on the Moon in return for lease charges and utilization licenses. The LDC would build and operate infrastructure on the Moon while managing a potential Lunar Site Registry, which would serve to offer protection from interference during the time of the license. Potential services amongst the offerings would include emergency rescue services, backup reserves of oxygen, water, batteries, trading outposts for mining equipment, food, the site-utilization registry, and developing common-use infrastructure, eg power plants and grids, landing pads and protective barriers. It is worth mentioning, for the record, that there was an earlier attempt, in 1996, by the former United Societies in Space organization to offer a similar concept - in that case referred to as the Lunar Development Authority (LEDA) – and which used the Tennessee Valley Authority founding documents as a model.

### **How will The Moon be regulated?**

These various entities, amongst others, are all trying to figure out what needs to be done to support and regulate this imminent Lunar activity. Ultimately, we shall need an internationally agreed Regulatory Agency for the Moon. At present it seems that this new regulatory regime will have to handle the following matters in an international context:

- Lunar Registry of locations and activities
- Safety zones and interference protection
- Protecting special areas (cultural Heritage Sites)
- Sharing of finite resources (eg water ice and power during the lunar night)
- Developing support services (eg common landing zones and rescue services)
- Ensuring use of best practices and common interfaces (docking and airlock equipment, life support, electrical, navigation, communications, etc) for sustainability.

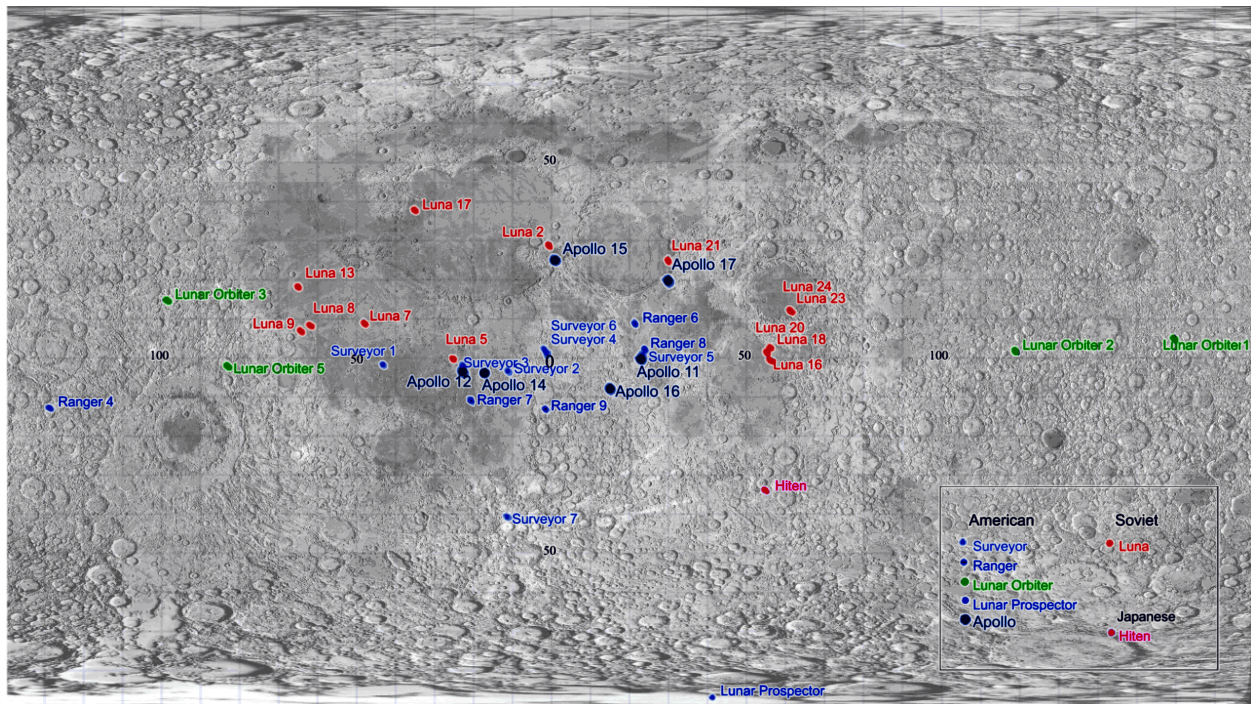
The idea that nation states are responsible, and therefore they must register and monitor their national commercial entities, is fundamental to all the international regulatory initiatives – and based upon the language of the Outer Space Treaty.

We now look at each of these key matters in turn, to investigate the likely practical issues remaining to be resolved....

### **The Idea of the Registry, Safety Zones, Interference Protection and Sharing Mechanisms**

As discussed above, the Heritage Sites are examples of locations around which there will need to be exclusion or safety zones. But, in order for this new phase of lunar commerce and development to work, it will be necessary to be able to identify the locations of all future operators, and to respect the notion of a safety zone around them, so that there are no problems of mutual interference. These kinds of

activities are routinely carried out in Earth orbit by the ITU and the associated national regulatory bodies regarding locations/orbits and frequency allocations for applications satellites. Starting with the Lunar Heritage Sites, there will need to be agreement on the appropriate safety zone dimensions for each site. There has been a good initial effort at providing this information, and it is included in the joint NASA/Smithsonian document *NASA's Recommendations to Space-Faring Entities: How to Protect and Preserve the Historic and Scientific Value of US Government Lunar Artifacts, July 20<sup>th</sup>, 2011*. The document provided for different safety zone dimensions depending on relative cultural importance of the artifact. It also recommended practices for avoiding causing damage from Lunar dust, including speed restrictions on rovers and altitude restrictions for hoppers. This was used for guidance by the Judges in the GLXP competition to ensure that competitors would not damage the Lunar legacy sites. It will eventually be necessary to establish international agreement, however, since there are historical artifacts on the Moon delivered by a number of different countries. Some sites will carry more cultural and historic importance than others, and this can be expected to be reflected in the size of their safety zones. The map shows some of the sites potentially requiring protection.



There are approximately 80 sites on the Moon representing soft and hard landings during the early phase of lunar exploration history. Some are indicated on this equi-rectangular projection map of the lunar nearside; there are also a few on the far-side.

A key element in regulating lunar activities will be the creation of a universally accepted Register of all actors and lunar sites. There has been some progress in this achieved by the ForAllMoonkind organization, focusing on the location and knowledge base at the Lunar Legacy sites. The ForAllMoonkind Registry has been created in Blockchain to ensure its security. And its status thus far, achieved by a volunteer Working Group (The Moon Registry Working Group), is that the following elements have been included for each of the legacy sites:

Object Name, COSPAR identity ref, mission type, operator, operator Country, Launch date, mass, dimensions, images, latitude, longitude, hazmat info (biological, radiation, propellant), last contact, heritage significance, condition report, information sources.

Other elements for inclusion in the Lunar Legacy Registry still under consideration are:

Place of manufacture, materials, maps, documents, site protection boundaries, statements of cultural/science/engineering significance, craft mobility info, deployed equipment data.

Also, a series of Review Processes have been established for the Blockchain update procedure to ensure that the Lunar Legacy Registry remains valid. Clearly, there will eventually have to be established an arrangement about who can include and update entries, and who can designate the relative merits of a site on a cultural or scientific or engineering basis. And these arrangements, by their very nature, will need to be international to be accepted.

Beyond the need to record the locations of Lunar legacy sites, there will be a requirement to add Safety Zones for all purposes of activity at all sites on the Moon, and to regulate and practice Interference Mitigation Measures. What kind of additional information will be required for these purposes in the eventual Registry? Some suggested headings include:

Location of site boundaries, Company, Commercial Purpose, Approved activity duration, Materials and Equipment used, Environmental Impacts.

There are other Registries, other than the ForAllMoonkind Registry, available as starting points for creating the definitive Lunar Site Registry, including the UN's Registry of Objects, each having differing information content. Initially, therefore, decisions will be needed on where to start, what kind of database to use, and how to coordinate content across the various source files.

There may also be a need while operating on the Moon to decide and enforce sharing mechanisms for certain rare resources, particularly when they are essential for sustaining life on the Moon. What are the special areas on the Moon deserving of our interest and possible protection or conservation? In the millennia since the Moon became synchronously gravity-locked with Earth, one face has always pointed towards Earth. Furthermore, as the Moon rotates once per month on its axis, this results in a month-long lunar day in which a gradually changing half of the Moon is experiencing total darkness (and cold) for two weeks each month, and the other half being in sunlight (and direct solar radiation). Due to the axis of orientation of its spin, and the uneven nature of its surface, the consequence is that there are some limited key areas at the poles which have either permanent sunlight ("Peak of Eternal Light", PEL) or permanent shadow ("Permanently Shadowed Regions", PSR). This situation may have resulted in the existence of water ice in these polar lunar craters. If so, this would represent a limited and finite resource – when its gone, its gone! Also, solar power could be generated at the peaks of perpetual sunlight to service power needs for lunar operations elsewhere on the Moon throughout the two-week lunar nights. So, these geographic areas on the Moon are indeed special, and limited. The lunar far-side as a whole represents a zone of special interest in that it is permanently blocked from terrestrial radio noise and Earthlight. This, and the lack of any significant atmosphere, makes the far-side of extreme interest to astronomers operating in the radio and optical wavelengths. We have a duty to protect, and find ways to share, these limited finite natural resources of the Moon. We have examples on Earth of both the protections for the Continent of Antarctica, the working arrangements on board the



International Space Station (ISS), and for the limited resources of the radio frequency spectrum and the Geostationary orbit, both administered by the UN organization the ITU (International Telecommunications Union). All of these have been successful examples of a global approach towards the fair sharing of limited resources, whilst simultaneously encouraging the continuing development of technologies for both public and private commercial purposes. However, almost none of existing national terrestrial law applies to the kinds of activities currently being envisaged for permanent human presence on the Moon. Even international space law has limitations to these kinds of activities, refers only to State actors, rather than individuals or commercial entities, and needs to be further developed and agreed in order to enable these future lunar endeavors. There is an important question requiring resolution. With regard to non-interference arrangements, which entity shall do the policing? The preferred approach emerging seems to be that the responsibility lies with the nation state who issues the license in the first place, and then must monitor its operations, via a state regulatory entity, making reference to the centralized registry database of lunar activities.

### **Common Interfaces and Interoperability / Best Practices**

Setting up business on the Moon, and indeed all potential future Lunar activities, will require that we build upon the lessons learned from our past achievements. The International Space Station (ISS) was successfully assembled and operates by following the tenets of the 1998 intergovernmental agreement (IGA). Now this agreement forms a good basis for understanding and implementing the norms for achieving long term and international sustainability during Lunar operations. The IGA carefully laid out responsibilities for integration and testing and common elements, including such critical items as docking and airlock equipment, life support/oxygen/water supplies, electrical/power networks, navigation and communications systems.

For our future purposes, with regard to navigation, for instance, it's all very well to have to avoid safety zones, but how do we even know where we are when we have no GPS, and no magnetic compass? How can we be sure that actors are remaining in their licensed zones if we are not sure where the boundaries are? How accurate can location and distance measurements on the Moon be? We can start answering this question by looking to history and considering how the navigation of the Apollo Lunar Roving Vehicle (LRV) worked. It used a combination of a directional gyro plus odometers and a sundial device, and the resulting accuracy was no better than +/- 6 degrees in bearing and +/- 300 meters in distance traveled during a 5 km traverse. The judges in the Google Lunar XPRIZE (GLXP) faced this same issue in trying to determine distance traveled, because prize money was associated with completing a 500-meter traverse. During Mission Plan Review tests at the Bangalore facility of Team Indus in October 2017, the judges observed comparative results from alternative measurement approaches (including wheel odometry, laser and visual odometry software techniques), which resulted in approximately 10 meters of uncertainty in the 500-meter traverse. In the event, the GLXP competition ended before any of the competing spacecraft were able to affect a Moon landing, but these tests were enough for the judges to require the teams to travel further than the indicated distance traveled by the assumed distance error in order to win a prize. Ultimately, however, we shall need the equivalent of a Moon GPS system available for all lunar operatives.

In the case of communications, there are still unresolved issues which will require agreement. At present, they are not even decided for the Artemis project, where it is still being decided whether to use

an orbiting Lunar Gateway as communications hub for high bandwidth communications. As the next phase of Lunar infrastructure is developed it can be expected that this will include coordination and use of a dedicated Lunar orbit telecommunications satellite relay system, using as yet to be decided orbital altitudes and frequency allocations.

### **The Need for Shared Services and Infrastructure**

As the new phase of Lunar Commerce and Infrastructure becomes operational, it will become clear that several shared support services will be required. The precise nature of these services is still to be determined, but it would be expected to include rescue services and maybe provision of common infrastructure such as landing zones.

### **Concern and Arrangements for Handling Environmental Issues**

Planetary protection protocols have been established by the Committee on Space Research, referred to as the COSPAR Planetary Protection Category II Guidelines. They require that a potential operator documents an inventory of organic compounds carried on, or produced by, any spacecraft – eg trace organics released by thruster exhaust. In the case of US operators, such documentation must be provided to the NASA Planetary Protection Officer for review. These guidelines were taken into account by the judges during the GLXP review process.

There will need to be developed guidelines specifically aimed at environmental factors, including human safety concerns, and during extraction and utilization of lunar resources. Amongst factors to be considered will be the impact of lunar strip mining activities with respect to visible defacement of the nearside of the Moon.

### **So, Now what?**

In conclusion, there is a way forward. There are a series of working agreements. There exists the basis of the necessary regulatory directory. However, there are still many gaps – but it is a matter of some satisfaction that there are groups of individuals, with international perspectives, who are all now working towards the opening of the Moon for business! This is the new frontier that will occupy us for the next several decades – so get involved with the action, and pick a piece of the puzzle that requires some fleshing out, roll up your sleeves and join in – and ensure your own contribution becomes part of the future of living, working and doing business on the Moon. After 50 years of absence, we are going back – this time for good!