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Ethical and Social Aspects of a Return to the Moon—A Geological Perspective

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Abstract: The forward planning of the return of Humans to the lunar surface as envisioned by different national and collaborative space agencies requires consideration of the fragility and pristine nature of the lunar surface. Current international treaties are outdated and require immediate action for their update and amendment. This should be taken as an opportunity for self-reflection and potential censoring, enabling a mature, responsible, and iterated sequence of decisions prior to returning. The protocols developed for assessing the ethical and social impacts of Humans on the lunar surface will provide a blueprint for planning future exploration activities on other planetary bodies in the Solar System and beyond.

Keywords: Moon environment; protection and preservation; holistic planning; update international treaties; Moon as an entity; exploration ethics; exploration versus exploitation; ethics

1. Introduction

Exploration and the search for the unknown are inherent characteristics of Humanity. The experience of setting and achieving goals is instinctive and fundamental to the development of Humanity and our understanding of the environment upon which we depend. These requirements cannot be taken without a robust and honest holistic assessment of our experiences as a species. This process will enable conscious and responsible decision making to minimise and (hopefully) avoid unforeseen risks and inadvertent mistakes. In preparation for the next generation of exploration of the Moon and the Solar System, Humanity needs time to assess the consequences. What kind of effects on the Moon and its stable and pristine environment will be caused by a return there (robotic and/or Human)? No action has a zero outcome and zero time for its execution: a full understanding is necessary of the whys, the "hidden" needs and desires of such endeavours, and whether it is a diversion from evaluating our Human "self". It is necessary to establish a coherent perception of nature's meaning of space and time, particularly from the "Westernised" perspective. As we plan the next steps in the cosmic venture, we also need to be able to acknowledge celestial bodies as entities that need to be respected, irrespective of their having life or not.

2. Discussion

The immense differences in the temporal and spatial nature of the cosmic and terrestrial ("Human") worlds effectively constrains Humanity from achieving complete intellectual appreciation. The average lifespan and experience of a Human, about 70 years, is a blip of the total time the solar system has existed. More than four and a half billion years–4,567,300,000 years (or 4.6 billion years; [1]) have passed since this part of the universe reinvented itself, and only 0.0000015% of this time is

experienced by an average Human during his/her life time. This gives Humans a very unrealistic sense of time, with a sense of urgency to accomplish as much as possible within those seventy years!

The past 4.6 billion years have witnessed major transformations on the Earth's surface, not only its environment, but also its continental configuration and occupation by different life forms. Evidence for these changes is succinctly catalogued in a chart known by geologists as the Geological Time Scale (see International Commission on Stratigraphy http://www.stratigraphy.org/icschart/cohen2013_episodes.pdf and references therein). The beginning of this time scale starts with the formation of Earth ~4.567 billion years ago (inferred to have formed at the same time as the Solar System) and ending today (0 years). This scale (Table 1) is divided into six major time segments, termed eons: Hadean, Archean and Proterozoic (these two grouped together as the Pre-Cambrian), Palaeozoic, Mesozoic and Cenozoic, which define fundamental changes in the rock record. For example, the distinction between the Pre-Cambrian and Palaeozoic (Cambrian) is the 'sudden' explosion of life. Evidence for this explosion is recorded in rocks as fossils and/or biomarkers (films of organic material formerly a part of a biological organism). Each eon is further subdivided into eras, which are further divided into periods, epochs and ages, enabling all levels of change in life forms and environment to be chronologically recorded, including major life extinctions, life renewal events and the predominance of other new species. It may be noted that the oldest preserved record of life suggests that life existed at least 3.77 billion years ago, or possibly as early as 4.28 billion years ago as suggested by [2].

2.1. Present Eminent Need to Evaluate Sense of Space Exploration

Currently, we are experiencing a global renewal of interest in space exploration. Aspirations are witnessed by the recent drive to develop space travel capabilities by different national space agencies such as the Japanese JAXA, the Chinese CNSA, the Indian ISRO, Russian ROSKOSMOS, the United States of America NASA and the European collaborative space agency ESA. All Humans at the beginning of this multi-national and multicultural effort have the responsibility to highlight concerns, provide suggestions and deliver comments relevant to the planned return of Humans to the Moon in particular, with the aim to encompass other planetary bodies in general. It is time for those countries leading renewed and expanded space exploration activities to see beyond individual national needs and consider holistically all other aspects relative to this venture. The history of Human exploration is long, and so it is a vast source of insight into the capabilities of Humans to do both good and bad, and to learn how to improve in the preparation and implementation of future missions. Currently available historical and environmental information can help us evaluate when exploration becomes exploitation, and how it affects the long-existing, pristine environments of newly "discovered" worlds.

There are several Human aspects which ought to be considered and revisited so that a more responsible and visionary approach to the next steps of Human "discovery" can be conceived and analysed in anticipation of the next steps in this explorative heritage. We need to contemplate once again the meaning of our lifetime, mortality, duty on planet Earth and connection to the remainder of the Solar System and cosmos. For at least the last 150 years, western Humans (mainly) have furthered themselves from nature with the increasing use of technology. These tools are becoming thicker intermediary layers between Humans and their sensing nature. They are functioning as barriers to our interaction with the environment that surrounds us and upon which we depend. Inevitably, our Human perception of dependence on the environment and its multitude of components has become reduced, and perhaps in some cases, completely neglected. This can be seen in what is the basis of the economic system we presently use, which depends on a parameter, energy, based especially in petroleum, which has an expiration date since it started being exploited, and which took millions of years to form. In part, this can be assessed as an unreasonable sense of superiority. The result is our non-immediate identification with the rest of life on Earth and dependence on the chaotic equilibrium of the natural environment we live in. There is an overall sense of detachment and non-belongingness to planet Earth, but rather, of it belonging to us. This detachment led to an outcome of irreversible changes (at least in the Human-time perspective) of our surrounding environment,

e.g., pollution in rivers, the plastic islands of the Pacific and Atlantic. However, and as it is possible to determine from the geologic record, Earth and life in and on it have always been able to renew themselves. For example, if the "catastrophic" event of the collision of a large asteroid with the Earth ~65 Ma had not occurred, then perhaps mammals would not have evolved to dominate, and we would not be here. Hence, it is important for Humanity to be conscious and accepting that we are here as dwellers and fundamentally depend on our host.

It may be timely in this discussion to ask whether we, as a species, are mature enough to understand the tools we have built and are able to fully evaluate and use their capabilities. Many of these tools have been developed out of caprice and not necessarily need. Technological developments have taken us far into great adventures and accomplishments. We have been able to dare to question the general cultural assumptions about the shape of the Earth: is it flat or round; the rotational relation between the Earth and the Sun: is the Earth the centre of the planetary system or is it the Sun? Humans have conquered oceans believed to be adorned by unforgiving creatures desiring to taste our flesh. We have many times been on the verge of extinguishing ourselves (while actually extinguishing other species ...) with innumerous wars and mistreatment of the environment we depend on. However, we keep on going to the limits, which are not well defined or imagined. We keep on daring our boundaries without being directed, but do we need to be directed, do we really know what are we doing? Are we ready to understand the consequences of our actions and simultaneously accept our vulnerability and powerlessness? This is the time to commence evaluation.

2.2. The Spiritual versus the Technologic Human: Need for a Holistic Perspective to Explore the Solar System

It is often argued that technological growth appears to move at a faster pace than our (sub)consciousness can assimilate and evaluate. Is it because (sub)consciousness is deeply connected to our biological transformation and evolution, therefore needing more time to digest all that our immediate technical mind puts out? This intrinsically assumes a western view point of the body and mind dichotomy. To better adapt to what is created via our imagination and hands, we may need to allow ourselves time to slow down to ponder. Namely, we need to evaluate all the suffering that is being inflicted upon Humans outside the more privileged parts of the world, together with global damage of the environment. This perspective is already currently in the minds of many scholars e.g., [3] who are advocating for slower to no growth. Imagine that aliens were sitting on some cosmic clouds and looking down at the Earth, contemplating Human daily life. It is easy to imagine their astonished minds surveying several billions of Humans running around in circles of no more than about 10 km in radius, causing immense particulate clouds, not being efficient with their resources and in a "I gotta-go mode" that does not allow them to evaluate their own life and the effects of their actions. It would be, in part, similar to when we observe ants in their endless mission of carrying stuff to their colony. The words of Arthur C. Clarke may be repeated here, from his book [4]: "We must not, however, commit the only too common mistake of equating mere physical expansion, or even increasing scientific knowledge, with progress"; however that may be defined. "Only little minds are impressed by sheer size and number. There would be no virtue in possessing the Universe if it brought neither wisdom nor happiness. Yet possessing it we must, at least in spirit, if we are ever to answer the questions that men have asked in vain since history began." While this rush is occurring, there appears to be a sense of global Human amnesia and an unwillingness to reflect on our vulnerability to drastic changes in our immediate environment as well as to the more distant, the cosmos. In this case, the concept of the Earth as a whole and its place in the Solar System should be introduced here. This idea has been extensively explored by James Lovelock is his book [5]. Earth exists in a 'busy' part of the Solar System where small bodies abound and their orbits cross the terrestrial orbit. These bodies are of varying size, shape and chemical composition, and there is plenty of evidence not only on the terrestrial surface, but also on Moon's, Mars', comets', etc. surfaces that the celestial voyage of these bodies may have a sudden termination as they collide with Earth (or any other planetary body).

Returning to a concept introduced earlier, it is of interest to the reader to further explain the geological time scale. The way these large time spans are expressed by geologists is by using powers of ten (e.g., 4.56 billion years is expressed as 4.56×10^9 years or simply 4.56 Ga (giga annum)). This simplification on recording time has the consequence of preventing Humans from recognizing how long life has occupied the Earth [6], or for that matter, the age of the Earth and the Solar System, and ultimately, the age of the cosmos. The numerical representation of time is a tool, but it does not offer us the sense or feeling to comprehend what all that time really represents. Similar to other tools (what the development of technology has offered us), Humans have perhaps been "robbed" of the sense of real meaning of time. On a more personal note, and considering that ones academic training is geology, and more specifically geochronology, these concepts of time (Human versus geologic) play a daily puzzle in one's mind. The experience of obtaining the age of rocks (and in specific lunar rocks) is perhaps one of the most astonishing and humbling experiences a Human can have: namely, the constant need to check on the self-indulged Human perspective of "most powerful and ultimate creation of nature". No matter whether Humans existed or not, planets, mountains and life would always have existed, disappeared or transformed. These long time and high energy processes are beyond our potential and perhaps right to alter, despite our permanent fooling ourselves with such thoughts.

If the geological record is studied carefully, it is easily observable that there are periodic instances of recycling of matter and energy which is most likely aided by events beyond our conscious understanding—those that we can easily grasp with our daily experiences and training. These events can perhaps be seen as part of "nature's program" of renewal of matter and energy. In the Hindu religion, the God Shiva represents destruction and creation, as there can be no creation without destruction. Table 1 shows the major markers in the geological time scale and types of life forms that better characterize them especially in the last 600 million years (My) representing the biotic "explosion". Nonetheless, initial attempts for life development on Earth started as early as 3.77 billion years ago, if not earlier [2]. Earlier attempts are usually suggested by scientists to have been interrupted by the frequent bombardment of the Earth's surface (not to forget those of the other parts of the inner and outer Solar System as well) by different impactors, as suggested by the lunar craters and sample records (e.g., [7–9]). However, changes in the global and local environment, together with the addition of cosmic nutrients delivered by these events, enabled the life we know today. How do Humans accept this sequence of constructive and destructive events? Should we accept it or should we think we are more powerful than nature and are able to overcome this path of evolution? Should we avoid such impacts and destroy threatening asteroids via the use of powerful laser-beams or other means, which would create many fragments of varying sizes and in random orbits? Or should we embark on another phase of migratory exploration into the Solar System? Or should we just let it be? These are the sort of thought exercises we should implement in this preparatory phase!

2.3. The Earth-Moon Cosmic and Human Connection

The lunar chronological record (or selenochronology) is used by scientists to infer understanding about impact events during the early times of the Earth-Moon system. The use of this tool involves two main assumptions: (1) the proximity of the two planets suggests that the flux of impacts on the lunar surface must be similar to that on the Earth, and (2) the geologic history of planetary evolution of these two planets is quite different. The Earth's crust is divided into plates which move relative to each other (plate tectonics). The two main features of this movement are that in some areas, new crust is being created (deep mid-ocean ridges, e.g., Atlantic mid-ocean ridge) and in other areas, the crust is being destroyed (subduction zones, e.g., Mariana Trench and Andes Mountains). Thus, the Earth's surface is constantly being recycled (on a geologic time scale), taking with it records of its past. Conversely, the Moon does not have plate tectonics, and its surface is composed of a superposition of past events from at least 50–120 Ma after formation of the Solar System [10–12]. In other words, the Moon can offer us a vast sequential array of information, with possible applications

to our understanding of Earth, offering a unique contribution to questions like "who are we?" where did we come from? how did we get here? and "what are we?" Therefore, the Moon is an excellent humbling vehicle which allows us to ponder and place a new perspective in our concept of time.

Presently and during the next steps of space exploration strategic planning, and in particular, with regard to missions to the Moon, it is imperative, and for preservation of Humanity's heritage as a whole that careful reflection on the impulses pushing us forward take place. What kind of impacts on the Moon and its stable and pristine environment will be caused by the return to the Moon (robotic and/or Human)? Here I make an appeal for an environmental and preservation awareness of the Moon, conscious that tangible sustainability of the lunar environment equates to not disturbing it, or in other words, no measure of "sustainability" post-disturbing this environment will restore it to its pristine nature that took about 4.5 billion years to form. The year 2019 will mark the 50th Anniversary of the Apollo 11 mission and a celebration of all its associated technical and scientific achievements. Now is arguably the perfect time to re-evaluate the environmental and selenologic impacts of these missions, notably the "controlled impact" of spacecrafts and related equipment onto the lunar surface, and the spread of debris, both lunar as well as Human-made, over the lunar surface associated with these Human decisions. Several Apollo missions performed experiments with the aim of studying the thin lunar atmosphere. It was demonstrated that the different activities of the astronauts affected this fragile layer due to the prolonged lofting of the fine dust particles resulting from the small gravity field present on this planet.

2.4. How Can Previously Acquired Knowledge Be Used as a Sign of Wisdom?

Humans already have plenty of information and experience to make sensible choices. As a lunar scientist and a geochronologist, one can witness how much knowledge has been gained through the analyses of lunar and samples from other extra-terrestrial material e.g., [13], and remote sensing observations of the Moon, and contributed for the understanding of the formation e.g., [14] and evolution of the terrestrial planets (including the Earth) by studying different types of meteorites. Until the 1960s (the Human space race, USSR and USA), the lunar surface had only been disturbed by cosmic and galactic material as part of the normal progression of things in space. With the advent of technological possibilities to send spacecrafts to the lunar orbit and surface, this cosmic environment was no longer unique by having been disturbed. Humans left vehicles, lunar modules, satellites, scientific tools, and purposely impacted orbiting satellites, etc. The Moon no longer is what it used to be from its birth ~4.56 Ga ago till the 1960's. It is estimated that there are a total of 189+ tons of debris on the lunar surface (https://en.wikipedia.org/wiki/List_of_artificial_objects_on_the_Moon). Nonetheless, scientific research has become vastly enriched, the public amazed, Human curiosity partly fed, and our wish to return suffering of insomnia! Lunar science is far from complete and is still in its embryonic stages. If we must return, to continue being Human and to go about challenging our physical and psychological selves, we must do it carefully and humbly. The celestial body closest to the Earth is an important, powerful and fragile environment that needs to be understood and taken into consideration before we finally set sail to it again. To get to our current state of knowledge, many decades, if not centuries, have been necessary—so patience may be a factor to take into consideration. Developments in technology may have cut short the 'waiting time', but Humans still need reasonable amounts of time to ponder and be prepared to responsibly continue the voyage into the Solar System. This Human time is still quite minimal in cosmic terms.

This paper is a call for patience and includes the concept of looking into our surroundings and analysing Human's impact on the environment: how many forests have been destroyed for us to build houses, burnt to provide warmth, and replaced by agriculture to fulfil our food supply? How many more mountains need to be carved so gold and rare earth elements for the numerous computer chips and touch-screens are extracted instead of recycled? How are the pools of acid required for the separation of these metals monitored, especially to avoid their percolating into underground water tables or infiltrating into soils? How many islands with pure and ideal sand for the making

of motherboards need to be destroyed to enable the consumption hunger imposed by the modern technologic society? When are we going to appreciate nature as it is without the feeling that we are the owners and can manipulate it at our whim? As a European, and a citizen of a former global colonial power, the need to discover runs in my blood. History, however, also records much of the negative impact caused by such ventures into unknown lands, which we must use to better prepare ourselves for new ones (see Table 1).

Table 1. Main Extinction and Resulting Biologic Development after These Events.

Era	Period (duration)	Comments
Cenozoic	Quaternary (2 My)	Humans dominate near the very end (last 100,000 years), and in the last 200 years there is another mass extinction. Rate of species loss is now estimated between 200 and 2000 species/year.
	Tertiary (65 My)	Mammals become dominant large animals, insects and flowers co-evolve.
	K/T mass extinction-due in part to a large meteor impacting the Earth in Yucatan peninsula area	
Mesozoic	Cretaceous (130 My)	Diatoms, dinoflagellates and other one-celled organisms become abundant as marine life. The first flowers (angiosperms) and first primates appear during this period.
	Jurassic (180 My)	Dinosaurs dominate on land. Birds first appear.
	Triassic mass extinction-35% of all animal families go extinct	
	Triassic (230 My)	Reptiles dominate the land, molluscs such as cephalopods dominate the oceans. Dinosaurs and marine reptiles appear in late Triassic. Atlantic and Indian oceans appear. First mammals appear during this period, but remain rare.
	Permian mass extinction-forams, corals, bryozoa, brachiopods, arthropods and crinoids	
Palaeozoic	Permian (270 My)	Reptiles dominate the land. Seas contract in mid-Permian leading to a decline in marine life.
	Carboniferous (350 My)-divided in Pennsylvanian and Mississippian	Large portions of Earth were submerged and covered by coal swamps with scale trees (lycopods) and seed ferns. Reptiles arose and diversified during this period. Warm shallow seas led to diversification of marine life.
	Devonian mass extinction	
	Devonian (400 My)	Widespread invasion of land by molluscs, arthropods and amphibians. Fish diversified and dominated the oceans.
	Silurian (430 My)	Invertebrates dominated during this period. In the late Silurian plants and possibly some animals invaded the land.
	Ordovician (500 My)	First vertebrates appear (jawless fish) and bryozoans and crinoids appear. Invertebrates dominated the period.
	Cambrian (600 My)	Called the 'Cambrian Explosion' when phyla appear: Sponges, archaeocyathids, brachiopods, trilobites, primitive molluscs, and echinoderms
Precambrian	Precambrian (~4000 My)	The Earth forms, cools, in the latter half of this era there is evidence of bacteria, cyanobacteria and stromatolites.

3. Conclusions

A future lunar return should be undertaken on a step-by-step basis to allow careful, balanced and scientific assessment of the current state of lunar knowledge to gradually learn from experiences and mistakes. This approach would enable exploration in a more responsible and respectful manner. There is an urgent need to update and amend both the United Nations Moon Treaty of 1979 (i.e., Agreement Governing The Activities Of States On the Moon And Other Celestial Bodies) and the Outer Space Treaty of 1967 (i.e., Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies). Future amendments and ratifications could use the Antarctic Treaty of 1959 and the associated Protocol

on Environmental Protection to the Antarctic Treaty of 1991 as exemplars for updating those treaties, as suggested by [15–17].

Humanity should see our existence and activities as contributions to future generations, not as the finalised end-product. Humans need to reflect upon their reluctance to deal with mortality and ethics, the desire to do "right here, right now" attitude and the tools (e.g., words) used in verbalization to hide this fear of introspection. We are bombarded daily with the notions of being responsible for our progeny, yet, in our daily activities, we forget about all of them. This potentially arises from the element of time and the strangling feeling that we may not accomplish everything we wish in our lifetime. This usually leads into great anxiety and little time is devoted to considering issues related to our position in time and space. Perhaps, it would be more helpful if Humans would think of our work (whatever it is) in terms of a contribution to the understanding of the big-picture of what Human history and heritage are. This could allow us more time to deliberate on issues and better accept our helplessness, but simultaneously, we could better appreciate our place in the Cosmos. This path would hopefully give us a different view of our activities in space as well as our motivations to explore it in a more scientific and spiritual perspective. Have we ever asked why Humans want to return to the Moon and then colonise it? Or does the Moon want visitors? In the myriad of periodic conferences, meetings and general discussions, there seems to be a clear notion of what people want from, of, on and at the Moon, but has the Moon been asked what *She* wants? Now is the opportunity for Humans to be less egocentric and see the implications of a possible return to the Moon beyond each personal life experience. There is a need to acknowledge the Moon as an entity beyond ourselves that needs to be respected.

What are the opinions of all the nations and cultures of the world on a return to the Moon? And how are the voices of their citizens being taken into consideration and included? In a globally shared endeavour, it is necessary to take into account different philosophies and approaches to what science and the cosmos are. We need to collectively look at the current world situation and think how we want it in the future! How are our actions really going to influence future Human and non-Human generations? Do we care? Who is going to be included in the decision making? What sort of benefits will it bring to Human kind and others—after all, Humans are not alone. Which nations will benefit? Will there be people, animals, plants that will not benefit from this endeavour? Presently, the USA, China, India, Japan and Europe are well represented, mainly by pioneering, engineering and scientific minds. However, the world is a vast place with many peoples, needs, wishes, and points of view. Also, a geological view of space exploration would not limit the planning to 5 to 10 years as most businesses practice. Instead, it would allow longer term planning or at least the development of a more solid mental infrastructure. The next visit to the lunar surface should perhaps be envisioned as the beginning of unified Humanity when the so-called "developed" and "developing" nations are to be seen as being on the same level, with each 'nation' being considered equally.

The past two decades have witnessed many conferences where the focus is on exploration/exploitation and utilization of the Moon. At these forums, recommendations for future lunar exploration are proposed with the main concept being: 'Together, we hope to bring the best of Humanity to the Moon, and to bring the benefits of the Moon to all people on Earth'. It is important, before the decision to colonize the Moon is taken, that Humanity as a whole has answered the initial questions of: Who are we, where did we come from and where are we going. Finally, it is imperative that Humanity understands what the Moon has to tell us in terms of our role in the universe and our cosmic inheritance!!

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