Letter of Intent for the ESA call “Cosmic Vision 2015-2025”

Sir,

with this Letter we respond to the “Call for themes for 2015-2025” opened by the Science Programme of the European Space Agency in view of its future long term Scientific Programme.

The theme we propose is ***“Our Laboratory Moon”*** which is based on the exploitation of the unique features of our satellite to study fundamental physics phenomena.

Space means exploration. Exploration in turn means searching for things never reached before. After the landing on the Moon with the Apollo missions, human space exploration is aiming towards the challenges of travelling to Mars. Robotic exploration is aiming to even more distant planets or comets. But there is also another kind of space exploration which is related to new perspectives opened by a change of system of reference. In the present proposal it means establishing a continued presence on a planet or satellite to exploit its resources and to explore the possibilities opened by the fact of being there. The advent of always more advanced telepresence techniques, give to the Moon a unique role in this regards. Establishing our telepresence on the Moon today would be much simpler than it was sending there the Apollo astronauts 40 years ago, but would give a tremendous return in term of science and perspectives. In addition to the more general interest of developing enabling technologies for a future human moon-base, this theme will allow us to exploit the extraordinary resources offered by our satellite to perform a set of fundamental physics and astrophysics experiments.

The proposed theme appears to be related to at least four of the grand themes outlined by the Cross Disciplinary Perspective Group (XPG) for 2015 and beyond, namely

- Nature of physical laws including their immutability in time.
- High energy physics beyond the accelerator.
- Quantum world, edges of space, cosmic microwave background and black holes.
- Universe: origin and evolution and changing nature of the universe

We are looking towards interacting with the members of the ESA review process committees for a introduction of such a theme within the next ESA long term science plan,

Best Regards

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as corresponding author on behalf of the scientists who expressed their support to the proposed theme

Signatures follow

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"Our Laboratory Moon"

Why the Moon ?

There are indeed a few reasons why the Moon would be an extraordinary laboratory to study fundamental physics phenomena:

1 Seismic activity on the Moon is very low, basically insignificant. Due to the lack of plate tectonics, the energy release per year is 10^{-14} times lower than the Earth. Moonquakes are driven only by the tidal deformation (excluding impacts) and occur when the Moon is near the perigee. These quakes are reproducible and predictable. Strong moonquakes are at ~ 10^{-9} mHz–1/2 at 0.1-1 Hz, 0.5-1.3 on Richter scale. The seismic noise level between moonquakes may be extremely low

2 The Moon does not have atmosphere nor water. This means that

2.1 there is no absorption of the radiation reaching our satellite from space. Vacuum is cheap.

2.2 the Moon is thermally quiet except at sunrise and sunset. Even a more stable thermal environment could be achieved by burying the instrument under the Moon dust.

2.3 there are no winds, no weather effects. Materials are not attacked by rust, they last unaltered for long periods (aside of thermal expansions effects)

2 The Moon does not have a magnetic field nor a magnetosphere.

3 The Moon has a continuous view of the whole Earth (or of deep space). On the far side the Moon is an extremely calm electromagnetic environment, shielded from the noise generated by our civilization.

Fundamental physics and astrophysics on the Moon

These characteristics make the Moon as very attractive place to perform fundamental physics or astrophysics which cannot be done on ground and/or which are particularly expensive to be space borne because of complexity and cost. A very incomplete list, based on ideas or proposal discussed by various groups and agencies, would include:

1- IR interferometry (limited by the atmosphere on most wavelengths) using two or more IR telescopes

2- Optical and near UV interferometry (limited by the atmosphere), using two or more telescopes

3- mm wave interferometry (limited by the atmosphere and artificial em noise)

4- Direct CMB measurements (limited by the atmosphere)

5- Continuous GRB monitoring (limited by the atmosphere)

6- A large aperture, large area post-GLAST Gamma Ray observatory (0.1 – 1000 Gev) (limited by the atmosphere)

7- A Cosmic Rays observatory to measure the composition and spectra at and above the knee region, to solve the 50 years long puzzle on CR origin and acceleration mechanism (limited by the atmosphere and requiring rather large areas equipped with particle detectors)

8- O(10^3) km laser interferometers for Gravitational Waves searches, to cover the region 10^{-2} Hz to 10 Hz, which lies in between the LISA and VIRGO/LIGO sensitivity ranges (limited by Earth ground seismology).

9- A very sensitive search for strangelets by measuring epilinear moonquakes (limited by Earth ground seismology).

In addition to fundamental physics and astrophysics experiments many more geophysics, planetology and earth observation experiments could be carried on in a renewed effort aimed to establish a scientific Laboratory on the Moon.

Being there staying here

The obvious drawback for such a Moon-based Laboratory is the difficulty of sending and keeping a human base on our satellite. This would take very large investments and, unless unexpected events, is at least 10-15 years in the future. However the continuous technological advances in the field of telescience and virtual sensing could brilliantly overcome this limit. The Moon, in fact, is the only celestial body which is within 1.5 light seconds from us: this is a short enough time for electromagnetic waves, which would allow the use of robotic tools operated from the Earth as simple extensions of ground based operators arms, hands and senses, like in the case of telemedicine and like it is not possible as in the case of Mars rovers, which are separated from us ~ 10 light minutes.

Investing on ESA SMART-1 development for electric propulsion and related technologies to travel to the Moon, this program would involve a series of one way Earth-to-Moon missions, without any sample return, to transport to our satellite a small set of teleoperated rovers and basic material and instrumentation to set up build and maintain the experimental facilities, including data collection and transmission. Some of these rovers will be devoted to the exploitation of lunar resources, a key step in reducing costs of further exploration. The composition of lunar specimens has been extensively studied since the Apollo missions. Industrial processes to exploit lunar surface are generally well understood, resting on technologies used on Earth for decades if not centuries. New available technologies might be also useful to harness the Moon. Applying these mature and less mature technologies on the Moon remains, however, a challenge requiring great ingenuity.

Many of these industrial processes can be developed and tested on Earth before trying it on the Moon, where one would learn how to do it in the real conditions. The first series of missions will be devoted to set up processing plants to extract basic components, like oxygen, aluminum and water from the lunar soil and to set up the power generating and storing systems to sustain future facilities through interruptions in solar availability. These missions should all aim to the same location to the Moon, which has been identified as the area of "perpetual sun" near the South Pole. Here hydrogen should also exist, although there is no agreement today on which form it takes. The presence of hydrogen and perpetual sun, would make this location the most advantageous for initial operation.

Additional missions, would add capabilities and instrumentations, with a philosophy which would be highly interactive and flexible. It should be as we were there, through the robots which are acting under our direct telecontrolling. This approach would allow to tolerate losses and mistakes, which, although unavoidable in an highly research oriented program, could have a tremendous damage and negative effects if humans were involved directly. Telepresence on the Moon is the goal of this pioneering program, allowing the rovers to operate like humans on tasks which would include rover repair activities, assembly and configuration of experiments, continuous feed back on many various parameters otherwise very difficult if not impossible to control using predetermined algorithms.

On the Earth, the operators will be immersed in a Moon-like virtual reality, operating as if they were there, but without any discomfort or risk. This organization would grant a tremendous pace of development of such a program, since trial and error and problem solving are the tools which allowed the evolution of our technology. This development would bring in a fast increase in know-how, approaches, tools and solutions, which would pave the way for the establishment of a human base on the Moon.

Of course not all materials will be produced on the Moon, only those which would be less costly to build there. Nevertheless the one which could be produced there would become the basic structural elements for the next generation of apparatuses to be assembled there. Complex assemblies (electronics, cameras, motors, and mechanisms) would come from the Earth, as compact, standard assemblies, to be attached to large, but simple, structural elements built there. This process would eventually bring to lunar self-sufficiency.

There are a lot of processes which would require, if performed in telepresence on the Moon, rethinking with respect on the Earth: the reduced gravity, absence of atmosphere, extreme temperature, limited facilities available, will call for simplification of manipulation and complexity of the processing. It will be like the dawn of a new age, not based on stones or fire or bronze, but more likely on solar radiation, hydrogen and aluminum. Tooling will be adjusted to the new tasks and conditions, in particular thermal condition would be of extreme relevance. Solar furnaces would be a common tool, soils would be heated to form glass and to shape rods, tubes and fibers. Sintering could be used instead of melting for a number of applications.

Machines shop capability could be gradually added to work on the various materials and ceramics built on the moon, adding tremendous flexibility to modify and repair existing equipment or to build new one. Experiments could then be created without waiting for another launch, reducing the turn around time for engineers and scientists to see their ideas become reality from decades to days. More sophisticated machining methods, like electron beam or plasma will be easily implemented because of the presence of vacuum.

Concluding remarks

We anticipate a strong public attention to the progress on a moon laboratory program based on telepresence. Public attention is particularly strong when space exploration is connected to humans but also to human related activities, like risk, error, trial, ingenuity. This explains why the public interest is as high as for a human mission, and may be even higher when a Mars rover lands or takes the first photograph of a stone, or even get lost on Mars. A lunar telepresence laboratory would bring daily new stories, about issues which are very close to everybody experience; it would allow to share some of the thoughts, decisions, trials; it would allow wide sharing through the internet of finding and results; it might allow sharing of lunar telepresence, which would set an unprecedented tool for a wide audience of non astronauts. In addition to the interest for new results about our universe, which is, in our opinion, the main reason for supporting this theme, public participation to this long term program would be very beneficial for ESA and space exploration in general.