An International Lunar Geophysical Year R.G. Cox[1] ,D. Dunlop[2], P.E. Clark[3] [1]Flexure Engineering Inc., [2]National Space Society/Moon Society, Washington DC, [3]Catholic University of America@NASA/GSFC, Greenbelt, MD 20771, (Correspondence email: Pamela.E.Clark@NASA.gov).

Purpose: We discuss the proposed Internaional Lunar Geophysical Year (ILGY) based on work being done in the new phase of lunar surface scientific exploration that has the potential to greatly enhance basic scientific understanding of solar system formation and current processes. Proposed lunar ISRU would apply this understanding to open cislunar space and the lunar surface for the economic utilization of the Earth's population [1,2,3]. Several fortuitous developments have combined to present unique opportunities to advance this agenda through the proposal for a declaration of an International Lunar Geophysical Year [4].

International Interest in the Moon: International interest and momentum for lunar exploration is at its highest since the days of the cold war, and the US-Soviet race to the Moon. In the last decade lunar orbital spacecraft have revolutionized prior understanding of the Moon with regard to the presence and abundance of frozen volatiles, the processes underlying their presence, and other fundamental characteristics including the fact that it contains the coldest known surfaces in the solar system.

Funded Mission Development: Several nations have committed to sending lunar surface mission during this second decade of the century. China with a Chang'e III mission scheduled for mid-summer 2013. Indian and Russia with a joint mission named Chandrayaan II and Lunar Resource in 2017, Russia with a mission called Lunar Grunt in 2015. Japan is also planning a Selene II mission in 2018. NASA has recently presented a mission concept of an Earth-Moon Lagrange 2 Gateway project which would provide a range of opportunities to develop technologies advancing access to the Moon, Mars, and asteroids. A new private initiative The Golden Spike Company, has announced its goal of providing lunar surface expeditions to potential nation state customers as well as private industry using the capabilities of launchers from Space-X and United Launch Alliance [5].

New Paradigm "Lunar Cube Hitchhiker" Missions: Parallel to this interest is the development of micro-engineering techniques and instrumentation which create the opportunities to create low cost, low mass, low volume, spacecraft with unique operating capabilities in the extreme environments on the Moon including ultra low temperature and low power electronics systems [6]. Advances in solar electric propulsion, including further miniaturization, of propulsion can propel and orient these small space craft. These are also being matched to lunar mission architectures and destinations . This new paradigm has been labeled Lunar Cube - Hitchhikers based on the cube satellite design paradigm [7]. These Lunar Cube craft rely on low cost secondary launch capabilities and opportunities to "hitchhike" on missions headed to Geostationary Earth Orbit or on to other destinations which provide trans lunar injection trajectories [8]. Several small lander projects are in development [9,10].

Google Lunar-X-Prize: Advancing this exploration agenda is the Google Lunar X-Prize competition This competition was announced in 2006 and open to teams from any where in the world that could land on the Moon, move 1500 meters, photograph its surroundings to prove its successful landing, and transmit these pictures to Earth for a first prize of $20 Milton dollars. A few have developed agreements for launch before the 2015 deadline. Some contenders, Astrobotics and Moon-X, have landers that can bring at least 100kg to the lunar surface. Astrobotics has a projected launch dates in October of 2015 while Moon-X has also indicated a 2015 launch [10].

Additional Opportunities for Lower Lunar Mission Price Points: Recently, Russell Cox of Flexure Engineering proposed an International Lunar Geophysical Year during 2017/2018 when the latest international landers were scheduledto advance both the scientific and commercial agendas [4]. To these currently approved international lunar landers landings might be added a number of other low cost missions which grow out of the Google Lunar X-Prize competition. First are missions such as those which hopefully will fly successfully to the lunar surface. Astrobotics and Moon-X for example can carry a number of small payloads and small craft. This capability will bring the price point for instrument delivery to the lunar surface to approximately $1M per kilogram. Small payload of just a few kilograms could therefore cost in the single digit million dollar range. Second are small lunar orbital and or surface lander mission costing in the low tens of millions. Such missions are within the reach of smaller countries in collaboration and similarly with many institutional budgets.

Google Lunar X-Prize teams not good at raising money have no practical chance of winning the first or second GL X-Prizes. This does not mean that they do not have interesting and worthwhile technological ideas and approaches. After the gold and glory of winning the Google Lunar X-Prize are gone there is still the potential of many groups to advance their projects to the lunar surface if extended objectives can be developed and demonstrated. These GXLP "also-rans" present opportunities for national space agencies and commercial companies to invest in their capabilities and missions. Some teams which will not win the

GLXP have advanced to a Phase A or "Phase B" stage of development. Such teams might perform useful science missions during a International Lunar Geophysical Year. They might also further the commercial paradigm of exploration that was both the intention of the Google Corporation, the X-Prize Foundation. NASA which has provided technical support in some cases like Moon-X and Astrobotics and Omega Envoy [4,10]. Team Space IL has also received approval to utilized data from the LOLA laser instrument now flying on the Lunar Reconnaissance Obiter [10] The Google Lunar x-Prize has characterized itself as Moon 2.0 in contrast to the Moon 1.0 of the Apollo era. The ILGY could mark the beginning of a new Moon 3.0 architecture paradigm with a commercial government partnerships in exploration**.**

Lunar In Situ Technology Testing and Demonstration: NASA for example has many technology programs which are intended to advance the state of the art with regard to operating in the extreme cold environment of the Moon and Outer Planets and moons. The Moon is the closest and cheapest place to test and demonstrate these technologies. Their testing and qualification in cislunar space and on the Lunar surface is a matter of significant risk reduction for larger deep space missions by providing a flight heritage and record of reliability. The NASA 2013 budget and projected to outlying years from 2014 through 2017 contains a total of $3.2 billion for these technology development program [11]. These programs are in many cases in advanced development and both testing and demonstrations of their capabilities might occur in a well coordinated program of small lunar hitchhiker missions [11]. NASA could support an ILGY initiative largely within its OCT budget by also engaging the next generation of scientists and engineering through a competed program involving its network of Space Grant funded Universities. Competitive Teams could propose such test missions working in partnership with existing NASA Centers and coordinating their efforts with both commercial and government secondary launch opportunities. This would continue NASA's role as a cutting edge provider of both science, technology and education by demonstrating a new low cost high capability exploration program. With its many international lunar science partners this proposal builds on the foundation of the International Space Station by pushing the frontier of international collaborative efforts out to the Moon.

A "Lunar Cube Hitchhiker" 50 Model: A flight program for the ILGY Lunar Cube Hitchhikers could be modeled on the QB50 Program of university developed Earth environmental monitoring satellites [12]. The NASA Lunar Science Institute has a network of international teams which might be enlisted in this scientific campaign [13]. This would allow NASA to both share the risks, costs, and rewards while still leaning forward in pursuit of its science, exploration, technology development, and education objectives. This challenge is not so much a matter of new expenditures as it is the coordination and optimizing of existing NASA efforts by the NLSI, Space Grant Consortiums, SMD, OCT, and HEOMD collaborating with DOD, commercial, and other international launch programs.

A Proposed ULA Partnership: The United Launch Alliance is active and interested in the use of it large vehicles for secondary payloads. They could be an obvious and immediate partner in this Lunar Cube 50 Hitchhiker as a matchmaker for both government and commercial customers that are purchasing the primary payloads. The trick here is to find ways to put these Lunar Cube hitchhiker mission within the envelope of risk that is acceptable for primary customers.

Instrument Flight Tests in LEO: NASA has made the decision to cancel its satellite launch program program [14], but SWORDs might be a low cost vehicle which could provide low cost LEO tests of some of these instrument [15] and the DARPA ALASA [16] program might also provide low cost LEO test opportunities in developing ILGY demonstration spacecraft and in demonstrating that such systems are of acceptable risk as secondary payloads on larger commercial or government launches. The constrained budget resources of an ILGY program Lunar Cube 50 project demands coordination of existing assets both domestic and with non-US partners. The matching of the talents of university teams with NASA Centers leadership can advance both science and commercial technology development goals that arise from the International Lunar Geophysical Year.

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