The International Lunar Geophysical Year: 2017-2018, R. Cox[1], D. Dunlop[2], P.E. Clark[1&3], [1]Flexure Engineering Inc., [2]National Space Society, [3]Catholic University of America, (Correspondence email: Pamela.Clark@Flexureengineering.com).

The new phase of lunar surface scientific exploration has the potential to greatly enhance basic scientific understanding of solar system formation and current processes. 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 [1] (ILGY). Such a declaration could play a role analogous to the International Geophysical year of nearly 60 years ago, in greatly increasing awareness of the significance and importance of lunar exploration. 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. Several nations, including China, Russia, Japan, and possibly the U.S., have committed to sending lunar surface mission during this second decade of the century. We propose that the ILGY be proclaimed in 2017/2018 when several currently approved international lunar landers landings as well as one or more other low cost missions growing out of the Google Lunar X-Prize competition may occur.

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 to private industry using the capabilities of launchers from Space-X and United Launch Alliance [2].

Parallel Development in CubeSat Technologies: 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 [3]. Several groups, including Planetary SYstems and Planetary Services, have 6U and 12U packaging/deployment systems under development, analogous to the 3U PPOD used by terrestrial CubeSats [4]. Advances in solar electric propulsion, including further miniaturization of main propulsion drive and micro-thrusters, as well as development of software to provide routine development of low energy trajectories to the Moon, can provide the basis for far more efficient transportation and control for cubesats as well as vehicles of any size, including larger dedicated 'buses' to provide transportation to the Moon. The United Launch Alliance has proposed, along with SpaceX, the development of Earth escape launch vehicles for CubeSats. ULA has also proposed a transportation system known as the 'mule' in collaboration with other partners [5].

Additional Opportunities at Low Price Points: Alternatively, Lunar Cube craft could rely on low cost secondary launch capabilities and opportunities to "hitchhike" on missions headed to Geostationary Earth Orbit, GEO, or other destinations which provide trans lunar injection trajectories [5], or to the Moon itself, as we describe below. Launch providers have expresses interest in this role and as such could facilitate 'matchmaking' opportunities for both government and commercial customers that are purchasing the primary payloads. The challenge is to put Lunar Cube 'hitchhikers' within the envelope of risk that is acceptable for primary customers.

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 [6]. 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 [6]. Team Space IL has also received approval to utilized data from the LOLA laser instrument now flying on the Lunar Reconnaissance Obiter. 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**.**

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 [7]. The NASA Lunar Science Institute has a network of international teams which might be enlisted in this scientific campaign [8]. 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.

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 [9]. 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 [9]. NASA could support an ILGY initiative within its Space Technology Mission Directorate budget by also engaging the next generation of scientists and engineers 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.

Testing in LEO: NASA has made the decision to cancel its satellite launch program program [10], but SWORDs might be a low cost vehicle which could provide low cost LEO tests of some of these instrument [11] and the DARPA ALASA [12] 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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