Future Missions to the Moon: Building a Strategy for Lunar Science and Exploration. C. R. Neal[1] [1]Dept. of Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notree Dame, IN 46556, USA. (neal.1@nd.edu)

Introduction: The proximity and the fact that humans have visited the lunar surface, have been interpreted as negatives for the US to continue science and exploration of the Moon [1]. However, thanks to a reinvigorated and vibrant Lunar Community, the Moon features heavily in the current NASA Planetary Sciences Division Decadal Survey [2]. A number of other countries have recently focused their space exploration efforts on exploring the Moon: SMART-1 (ESA); SELENE/Kaguya (Japan); Chandrayaan-1 (India); Chang'e-1 and -2 (China). In addition, the US missions GRAIL, LRO, and LADEE continue to add to our knowledge of the Moon and the inner Solar System. Finally, the ISECG has produced a Global Exploration Roadmap [3] that develops a "Moon-first" approach to Solar System exploration.

The Decadal Survey [2] specifies 2 New Frontiers class (cost cap $1billion) lunar missions are highlighted: Sample return from the South Pole-Aitken Basin; a long-lived Lunar Geophysical Network. The decadal also highlights important lunar science issues that should be addressed by future missions:

- Determining the nature of polar volatiles;
- Understanding the significance of recent lunar activity at potential surface vent site;
- Reconstructing the thermal-tectonic and magmatic evolution of the Moon;
- Determining the impact history of the inner Solar System through the exploration of better characterized and newly revealed lunar terranes.

Interestingly, the decadal goes on to say that such missions may include orbiters, landers and sample return.

LEAG has developed, through community input, the Lunar Exploration Roadmap (LER) [4] that is updated annually. This large document is a comprehensive view of how to explore the Moon to further lunar science, develop capabilities to visit othe places in the Solar System, and develop commercial on-ramps with a view to making lunar exploration sustainable and permanent. In 2011, LEAG submitted to NASA 3-phase outline plan for enabling the LER [5]. Pivotal to this was the development of lunar ISRU and a technical demonstration that would extract, refine, and store resources on the lunar surface.

Phase 1: *Lunar Resource Prospecting*. Robotic prospectors on the lunar surface will quantify the the extent of resources identified from orbital data;
Phase 2: *Lunar Resource Mining*. Based on the results of Phase 1, an end-to-end resource miner feasibility demonstration would be deployed to 2-3 areas with the most abundant and extractable resources;
Phase 3: *Lunar Resource Production*. Based on the results of Phase 2, a larger-scale continuous processing capability would be deployed to the most appropriate site. Greater quantities of resources will be produced and be used to undertake more extensive demonstrations such as life support, mobility technologies, and fuel for a robotic sample return.

It is exciting to hear that "Resource Prospector" is a NASA HEOMD Class D mission in pre-Phase A [6]. This carries the Resolve payload [7,8] to the lunar surface and is tentatively scheduled to launch in 2018. In fact, there are several robotic missions planned to go to the Moon over the next decade (Table 1).

Table 1: Future Lunar Missions

COUNTRY	NAME	TYPE	YEAR
China	Chang'e 3	Lander	2013
USA	LADEE	Orbiter	2013
Private	GLXP	Landers	2014
India	Chandrayaan-2	Lander	2015
Russia	Lunar 25 (Glob)	Lander	2015
Russia	Lunar 26	Orbiter	2016
Russia/India	Lunar Resource 1	Lander/Rover	2017
China	Chang'e 5 (sample return)	Lander	2017
USA	Resource Prospector	Lander/Rover	2018
Japan	SELENE-2	Lander	2018?
Russia	Lunar 27 (Resource2)	Cryo SR	2019
Russia	Lunokhod 3	Rover	2020?

The Future. The Lunar Community needs to organize so strong Discovery proposals are submitted that cover many (if not all) of the lunar mission call-outs in [2]. In addition, with the number of international and even private missions planned (Table 1), we should lobby for regular SALMON calls so US scientists can be involved. We also need to support Resource Prospector, as well as MoonRise (SPA sample return resubmission). We have to be proactive in advancing our science and exploration the Moon.

References: **[1]** Obama B. (2010) *http://www.nasa.gov/news/media/trans/obama_ksc_trans.html* **[2]** NRC (2011) Vision & Voyages *http://www.nap.edu/catalog/13117.html* **[3]** ISECG (2011) Global Exploration Roadmap *http://www.globalspaceexploration.org* **[4]** LEAG (2013) *http://www.lpi.usra.edu/leag* **[5]** LEAG (2011) *http://www.lpi.usra.edu/leag/reports.shtml* **[6]** Colaprete A. (2013) *http://lunarscience.nasa.gov/lsf2013/agenda* **[7]** Captain J. et al. (2010) *SRR XI http://www.isruinfo.com/index.php?page=srr_11_ptmss* **[8]** Sanders G.B & Larson W.E. (2010) SRR XI *http://www.isruinfo.com/index.php?page =srr_11_ptmss*