Polar Resources

The Key To Development of Cis-Lunar Space

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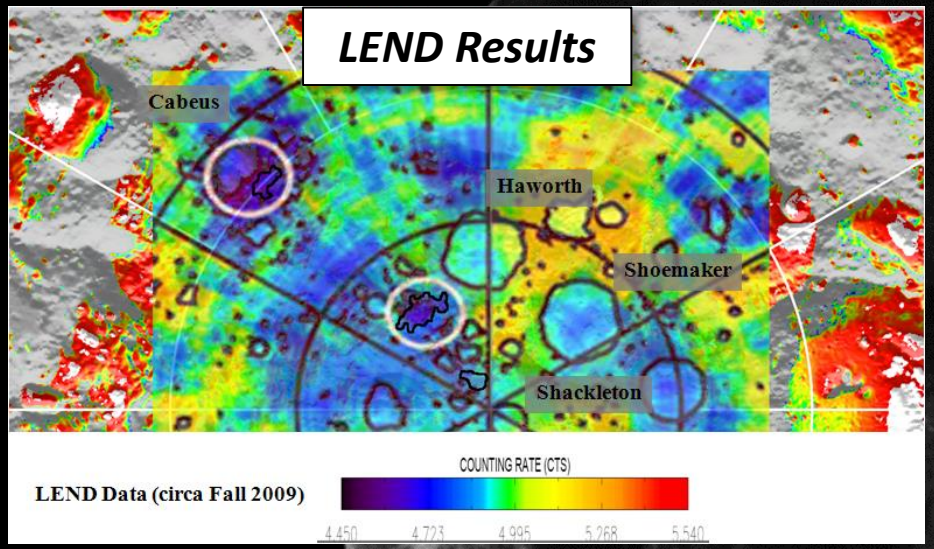
Going Back to the Moon to Stay

- There are plenty of unanswered science questions regarding the Moon that justify surface missions
  - However the rate of science missions launched remains painfully slow
    - Google X-Prize Landers may offer more opportunities, but the jury is still out
  - Science alone will not be enough to sustain long term interest in the Moon by the Congress (or the Public) nor will it generate a frequent mission rate
- We need something that drives a frequent and continual reason to go to the Moon
  - Lunar tourism not practical in the near term
  - Lunar Resources can be the economic driver that enables regular access to the lunar surface

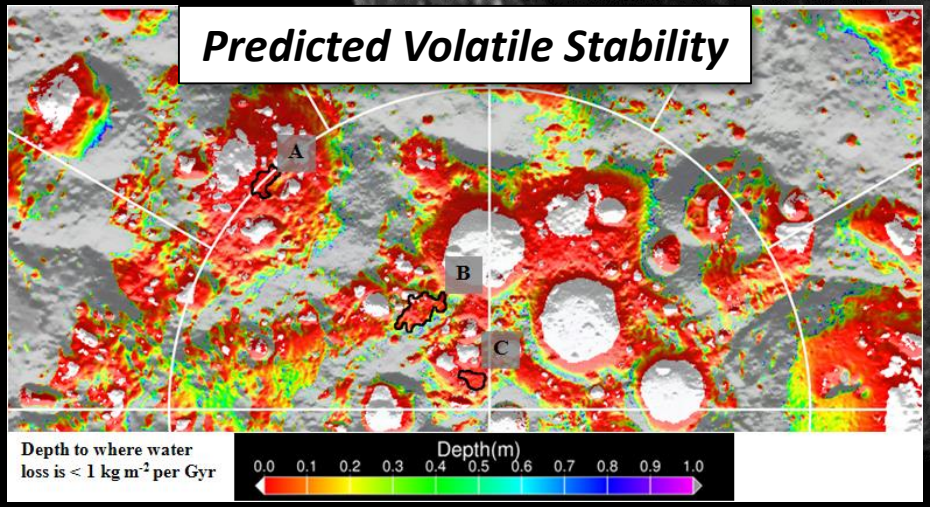
LCROSS Found Water and Other Useful Volatiles

					Instrument			
	Column Density (# m^{-2})	Relative to H2O(g) (NIR spec only)	Concentration (%)	Long-term Vacuum Stability Temp (K)	UV/Vis	NIR	LAMP	M3
CO	1.7e13±1.5e11		5.7	15			x	
$H_2O(g)$	5.1(1.4)E19	1	5.50	106		x		
H_2	5.8e13±1.0e11		1.39	10			x	
H_2S	8.5(0.9)E18	0.1675	0.92	47	x	x		
Ca	3.3e12±1.3e10		0.79				x	
Hg	5.0e11±2.9e8		0.48	135			x	
NH_3	3.1(1.5)E18	0.0603	0.33	63		x		
Mg	1.3e12±5.3e9		0.19				x	
SO_2	1.6(0.4)E18	0.0319	0.18	58		x		
C_2H_4	1.6(1.7)E18	0.0312	0.17	~50		x		
CO_2	1.1(1.0)E18	0.0217	0.12	50	x	x		
CH_3OH	7.8(42)E17	0.0155	0.09	86		x		
CH_4	3.3(3.0)E17	0.0065	0.04	19		x		
OH	1.7(0.4)E16	0.0003	0.002	>300 K if adsorbed	x	x		x
H_2O (adsorb)			0.001-0.002					x
Na		1-2 kg		197	x			
CS					x			
CN					x			
NHCN					x			
NH					x			
NH_2					x			
NH^S					x			
NH					x			
HNCO					x			
CH					x			

LRO Data Suggests Water Ice May Be Found Outside of Permanent Shadow



- LRO Neutron Spectrometer sees elevated hydrogen outside of permanent shadow



- Subsurface temperature models suggest water ice could be stable just 10 cm below the surface

Kick Starting the Cis-Lunar Economy

- Is there a market for lunar source propellant?
  - Numerous studies suggest the answer is yes.
  - ULA study* published in 2016 suggests a demand for >1000 MT/year for lunar propellant
- Unknowns and technical risks still inhibit the development of this market
- NASA is key player in buying down that risk
  - Surface prospecting mission is needed to understand the local distribution/concentration of water ice at the poles
  - Pilot plant demonstration of water harvesting and propellant production

*George Sowers, United Launch Alliance, Space Resources Roundtable, June 2016

Lunar Surface Prospecting

- Prospecting of a lunar pole to take place in the early 2020's
  - Resource Prospector* mission is about to emerge from Phase A and plans for a PDR in 2018 & CDR in 2019.
    - Based on the RESOLVE payload that was initially funded during Constellation Program
    - Will map the vertical and horizontal distribution of water ice in a partially sunlit region and in a permanently shadowed crater

2010 Field Test

2012 Field Test

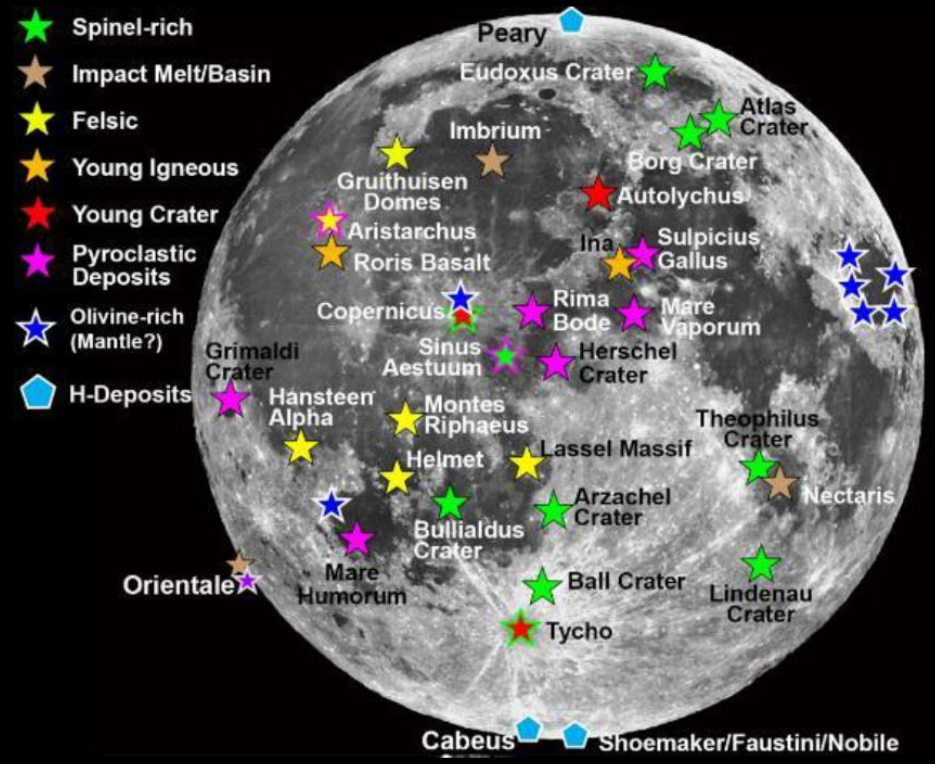
2015 Field Test

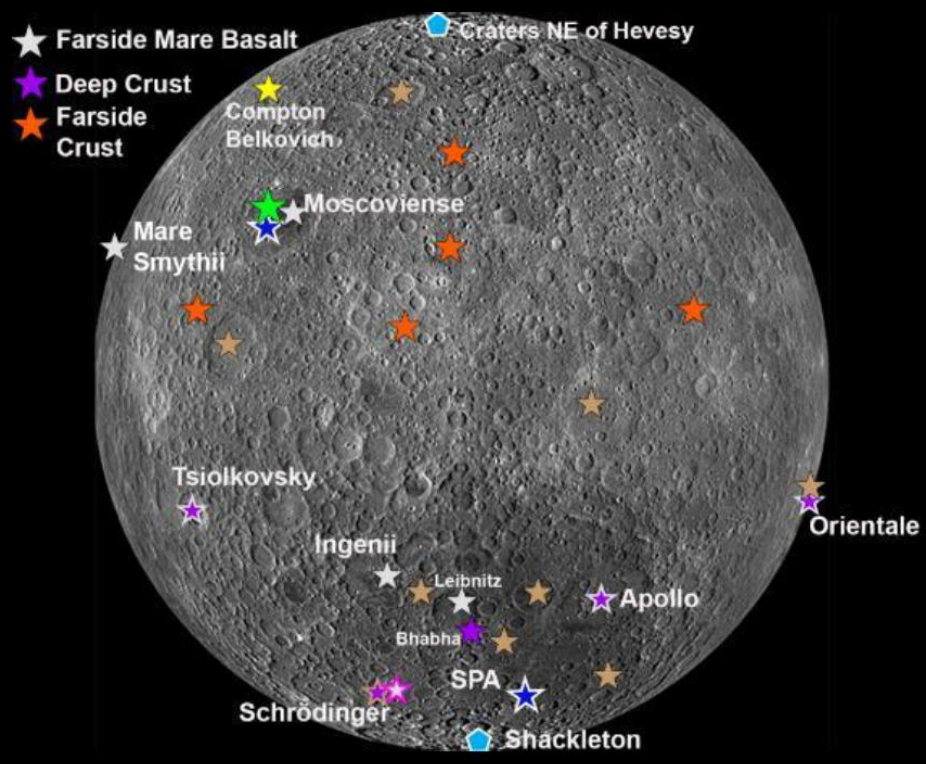
* http://www.nasa.gov/resource-prospector

RP Success Will Trigger Chain of Events

- RP provides the data needed to design follow on mission
- Phase 2 will be a Pilot Scale Demonstration of Fuel Production
- Phase 3 scale up to provide fuel for reusable landers
  - Commercial involvement begins to kick in
- Phase 4 Frequent access to areas of scientific interest on the Moon w/reusable landers and lunar-sourced propellant

Lunar Resources Will Enable Access to All Areas Of LEAG Interest





Opportunities for Sample Return:
LEAG Presentation to Decadal Midterm Review