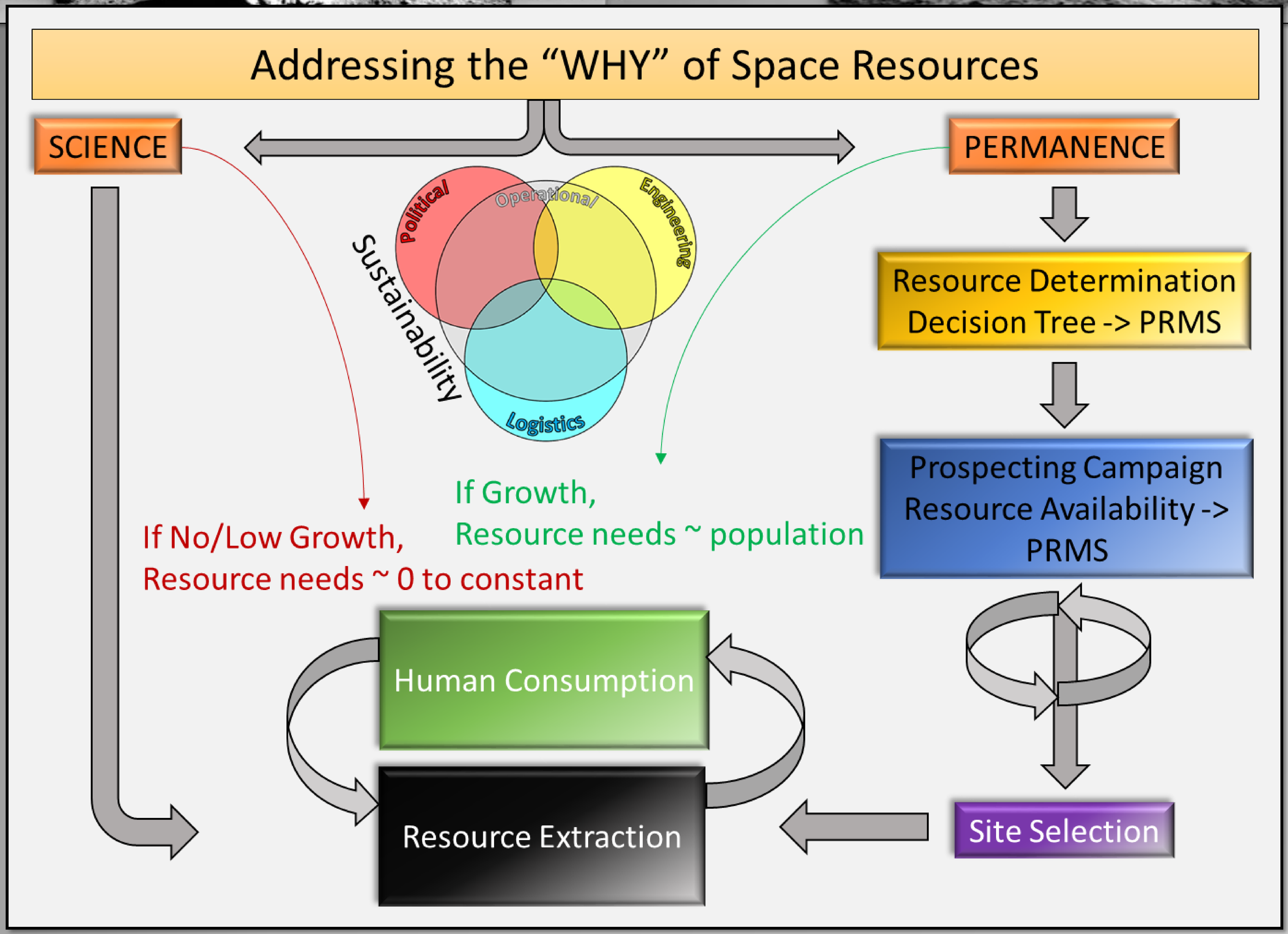
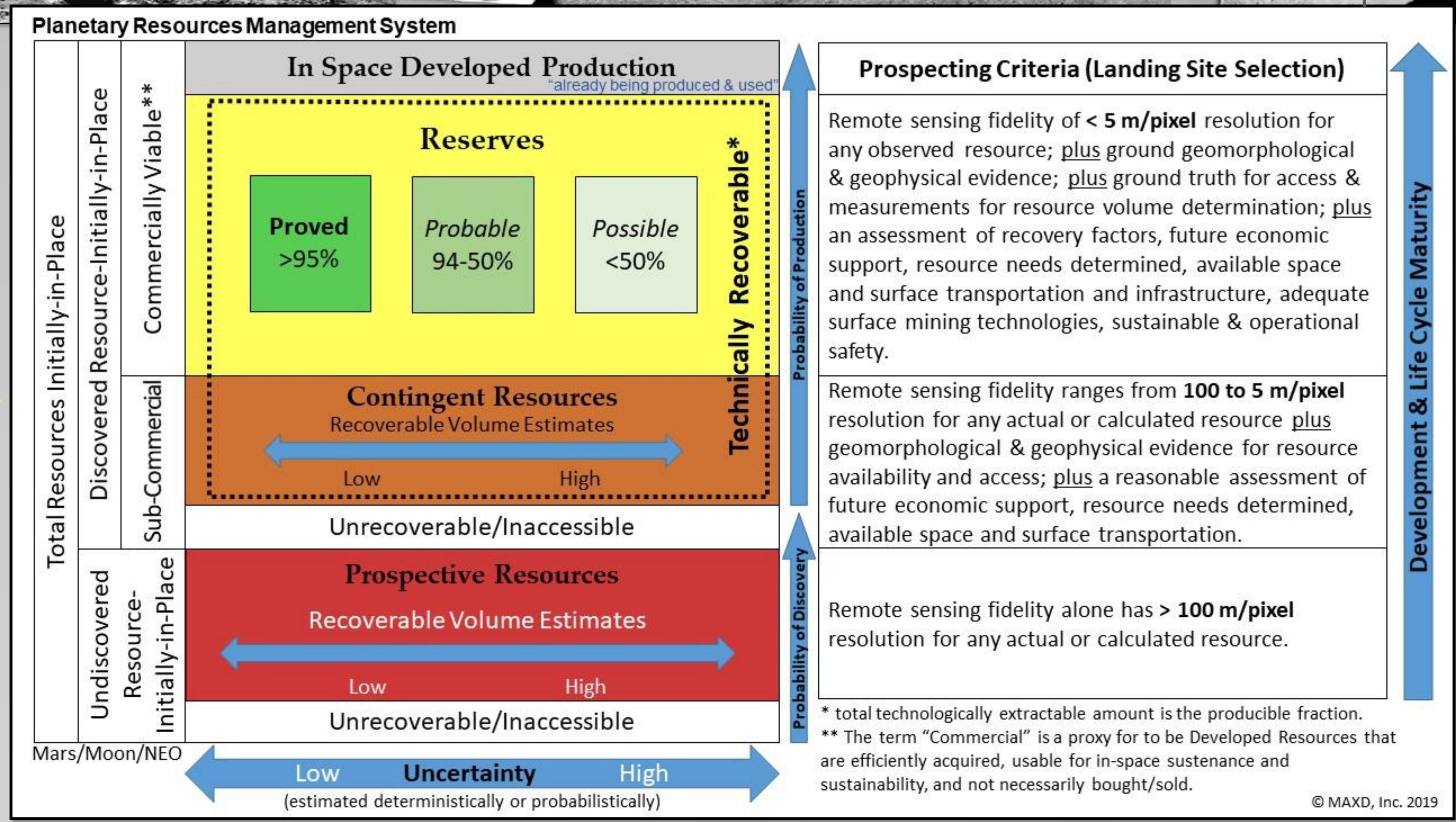
Lunar ISRU 2019
First Lunar In Situ Resource Utilization (ISRU) Workshop
July 15-17, 2019
Baltimore, MD.

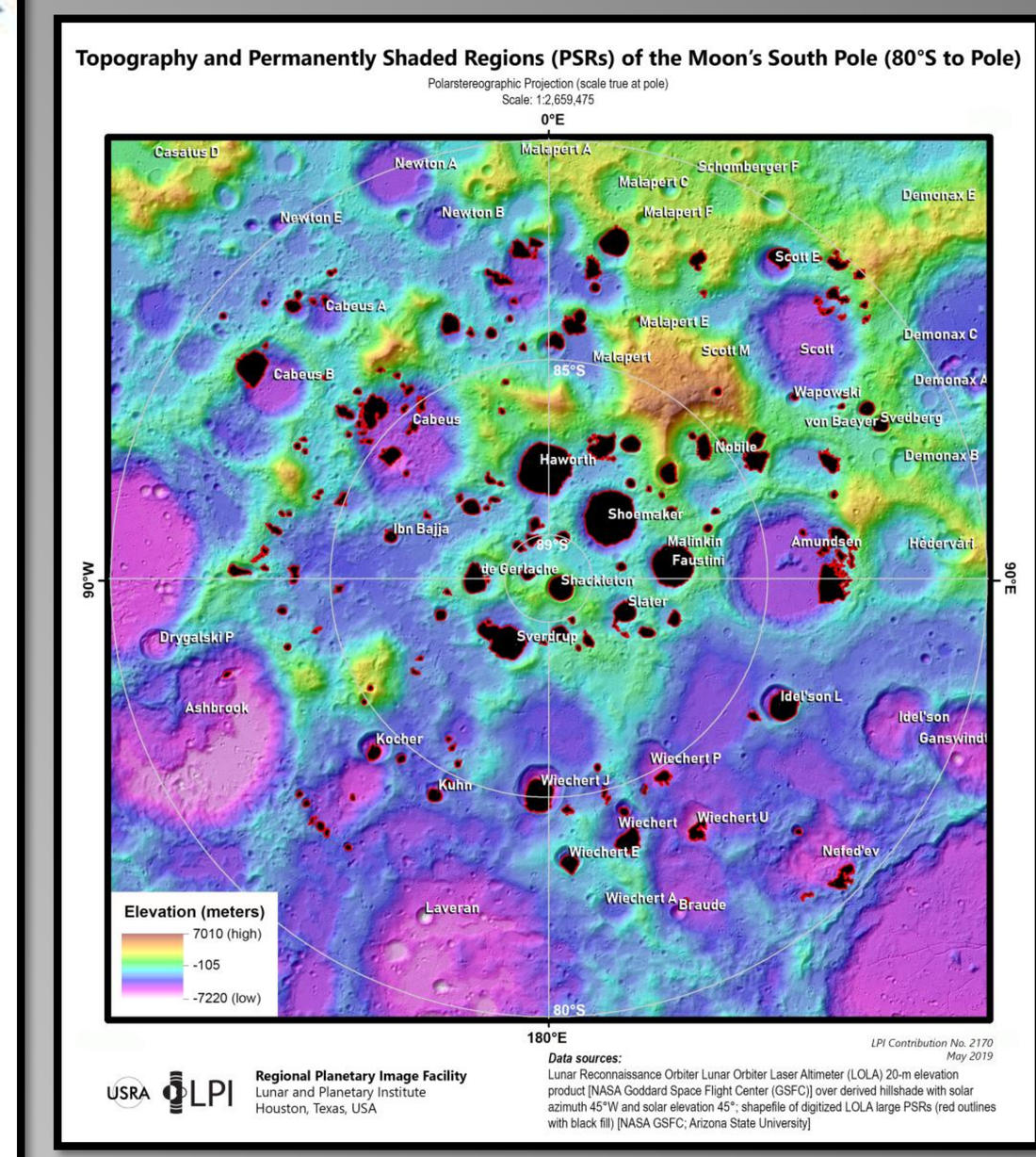
LUNAR RESOURCES: FROM FINDING TO MAKING DEMAND

By Donald C. Barker
MAXD, Inc.

Apollo 17, Station 6, Panorama







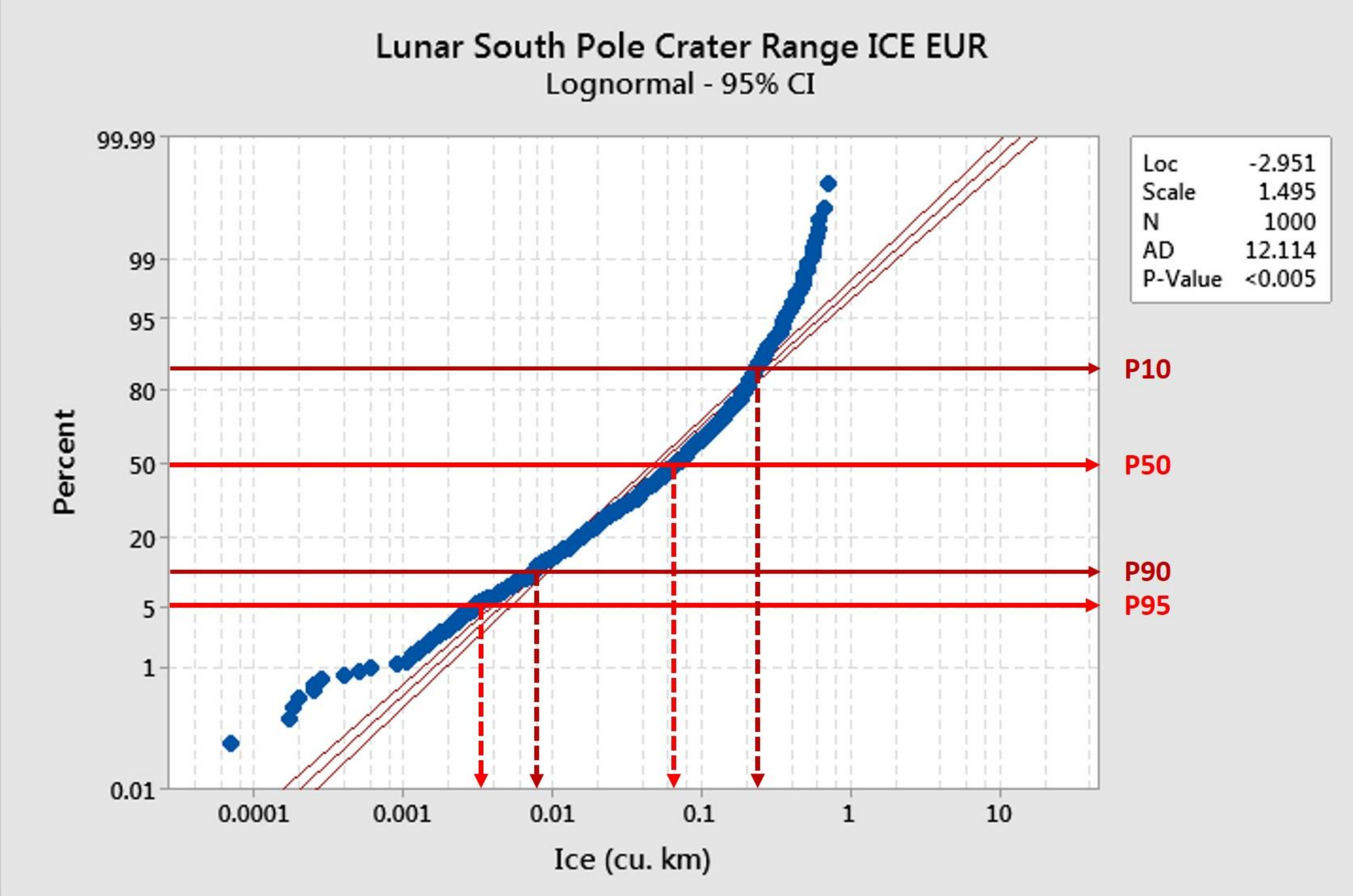
Water/Ice is the most critical off Earth resource. The *potential* exists for this resource within the permanently shadowed regions (PSRs) and craters at the lunar south pole, yet needs to be proven.

Simplified schematic (left) depicting interrelated conditions necessary to support and develop a long-term and sustainable human presence off Earth. Both the Science and Permanence sides of "WHY" may follow the same basic steps through resource acquisition, but due to lower expected resource NEEDs of lower population science driven missions, sustainability and resource requirements remain in question.

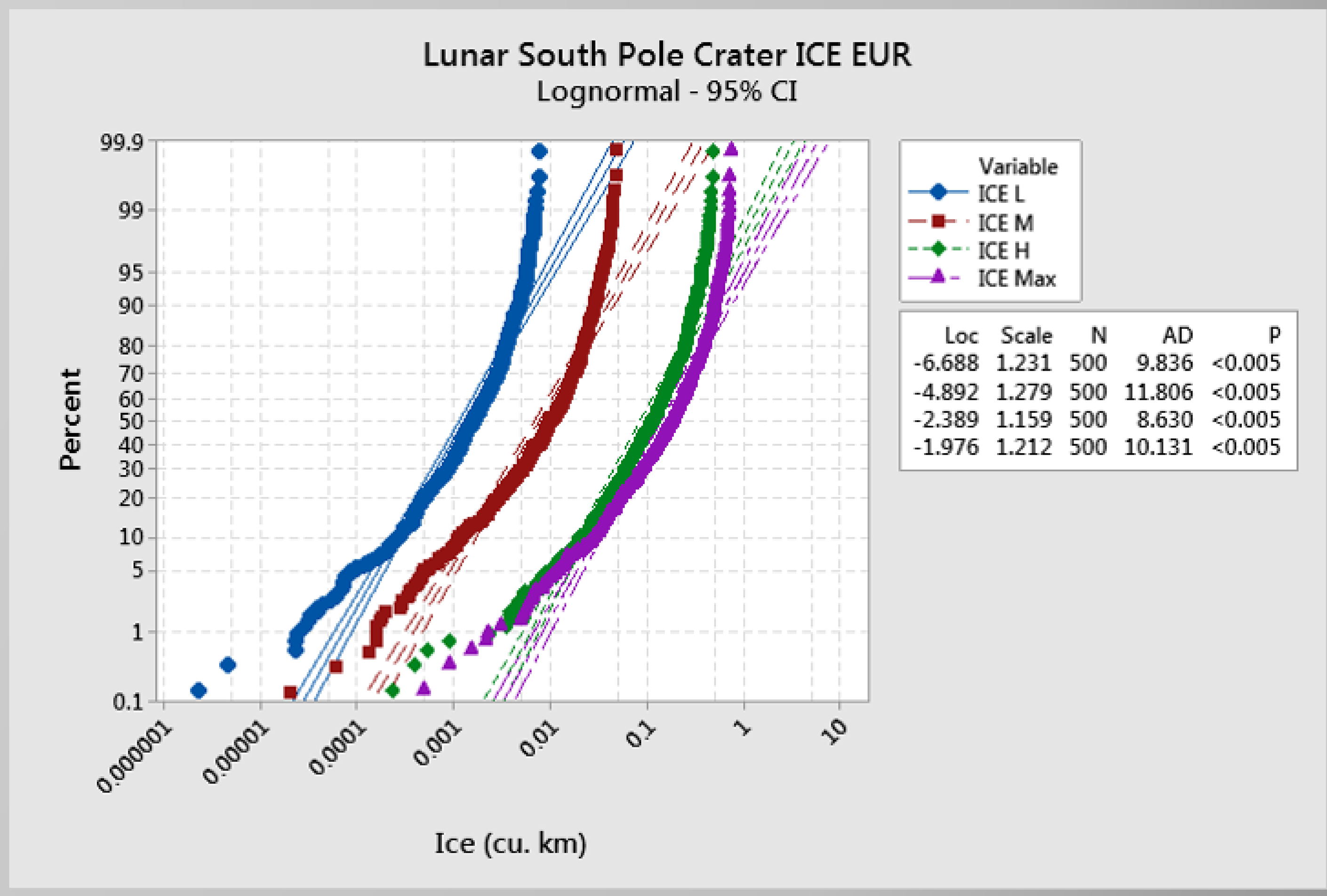
A human landing site should only be selected when sufficient resource knowledge is available via iterative prospecting (e.g., singularly focused precursor missions) combined with the use of the Planetary Resource Management System (PMRS) or similar tool (right), which provides guidelines and capability levels needed to identify, access and develop desired resources (space agencies do not have the luxury of drilling a "dry-hole" after humans arrive).

In order to create decision point cutoffs for the *Proved*, *Probable* and *Possible* Reserves categories in the PRMS model, an Estimated Ultimate Recovery (EUR) assessment is required. This is an example of a simple EUR analysis for water-ice within lunar south pole PSR craters, based on observed areas, and estimated depth, ice content in the regolith and a purported extraction efficiency from the literature.

The EUR represents a full life-cycle look at a potential resource asset and provides indications for success in resource extraction. It is an estimate of how much of a resource will ultimately be recovered from a reservoir before the source region is ultimately abandoned. An EUR is unique to each developer/user and is based on economic assumptions that vary among organizations. The most conservative probability used here is the P95, which indicates the *potential* of recovering approximately 0.0038 km^3 of water-ice from any PSR regolith. Lake Baikal for comparison, contains 23,013 km^3 fresh water.



EUR Monte Carlo model of probable water-ice equivalent content across full aerial range of established PSR crater areas from 10.001 to 1075.518 (km^2) - https://www.lroc.asu.edu/psr/list.



EUR Analysis of probable water-ice equivalent content across individual range of established PSR crater areas (km^2) focusing on 4 key sizes: L = 10.001; M = 62.19; H = 663.93 and Max = 1075.518.

IN SPACE USERS: Resource "needs" will be ultimately and possibly only, driven by in-space human populations. Taking a proposed SpaceX growth rate (max rate example below – 100 launch and 75 return every 6 months), it would take about 23 years to have a permanent resident working population the size of the summer population at McMurdo base in Antarctica (1200 people). This outlook and growth information must be understood as it will be the primary driver for resource consumption and needs going forward. Here we assumes all missions go to same destination and create a growing infrastructure. A consequence of this *permanence* approach is that all efforts on the lunar surface must go into one sustainable infrastructure, and that until such time as the base is functionally established, no/few science activities at other, distal sites, would likely be enacted. But, by the simple fact that people will be going there, scientific research, beyond ISRU, will be conducted.

2028	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mission 1						Mission 2					
Traditional (NASA)	4/launch & 3/4 return											
	4	4	4	4	4	4	5	5	5	5	5	5
Enhanced NASA	40/launch & 3/4 return											
	40	40	40	40	40	40	50	50	50	50	50	50
SpaceX (Musk)	100/launch & 3/4 return											
	100	100	100	100	100	100	125	125	125	125	125	125

2029	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mission 3						Mission 4					
Traditional (NASA)	6	6	6	6	6	6	7	7	7	7	7	7
Enhanced NASA	60	60	60	60	60	60	70	70	70	70	70	70
SpaceX (Musk)	150	150	150	150	150	150	175	175	175	175	175	175

2030	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mission 5						Mission 6					
Traditional (NASA)	8	8	8	8	8	8	9	9	9	9	9	9
Enhanced NASA	80	80	80	80	80	80	90	90	90	90	90	90
SpaceX (Musk)	200	200	200	200	200	200	225	225	225	225	225	225

2031	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mission 7						Mission 8					
Traditional (NASA)	10	10	10	10	10	10	11	11	11	11	11	11
Enhanced NASA	100	100	100	100	100	100	110	110	110	110	110	110
SpaceX (Musk)	250	250	250	250	250	250	275	275	275	275	275	275

2032	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Mission 9						Mission 10						
Traditional (NASA)	12	12	12	12	12	12	13	13	13	13	13	13	13
Enhanced NASA	120	120	120	120	120	120	130	130	130	130	130	130	130
SpaceX (Musk)	300	300	300	300	300	300	325	325	325	325	325	325	325