Lunar ISRU Focus Group members: The development of the in-situ resources of Oxygen and Water are prioritized by NASA and thus this Focus Group, though metals and other resources will also be considered. How separately or combined should we treat the discussions around the extraction, processing, and storage of O_2 and H_2O as we enable the development of technologies for a sustainable ISRU lunar architecture? (Note: A more formal "Confluence" website will soon replace this Google doc, though everything will be copied over and there will be a more interactive chat tool as well.)

The objective of this document is to REFINE the QUESTIONS that our FG will discuss. We do NOT want to track potential answers to questions here (apologies for the deletions of responses by those of you who have already done so! Separate Google docs will be set up to discuss the answers to these specific questions.)

Given the number of questions possible, please keep them big-pictured yet with the possibility of **definite answers**. Our eventual goal is to answer these questions through discussion; discussion itself is not the goal.

Also, from now on, let us NOT keep track of names as that may result in unwarranted opinion one way or another. Please add postings. However, only the FG facilitators (Karl, Michael, Kirby) are allowed to delete or modify a posting; given technology limitations, this will be on the honor system.

After we refine these questions, we'll next prioritize their importance for resolving/answering. After that, we'll discuss them with the objective of answering them and/or conducting a technology gap analysis.

What do you want to talk about and decide concerning O2 extraction, processing, and storage?	**What do you want to talk about and decide concerning water extraction, processing, and storage?**
Example: How do mare and highlands mineralogy compare in molten regolith electrolysis O_2 extraction amounts?	Example: How much hydrogen and oxygen does it take—and regolith tonnage by extension—to refuel a ____ lander?
Maybe another way to ask: What are the compositional dependencies in O2 extraction for MRE (molten regolith extraction), for CTE (carbothermal extraction), or other technique? How are rates affected? Processing temperature? Any concern about 'poisoning' of the process by nefarious components? other?	Given H2 is so much less massive than O2, and also several of the HLS systems use CH4/O2, let's focus on O2 use. So, how about: "How much O2 will be needed to refuel the potential HLS landers and ascent vehicles? Can other vehicles, such as CLPS landers benefit and if so, how much O2 would be needed? IE. how much in-situ O2 per unit time will be needed by what year and at what

	locations?
What can oxygen be used for? (that someone will pay for). Or “What are the primary drivers/users for future use of in-situ oxygen?	How well do we need to define the water resource for providing sufficient information that related technology development can proceed? Or is our knowledge of the horizontal and vertical distribution, abundance, and physical state of the ice already sufficient?
Some extraction techniques produce by-products such as metals. To what extent are these other products useful? Are their extraction a consideration for private industry or NASA?	If more information on the ice distribution is needed, what specific measurements do we recommend?
How much Oxygen can be generated from regolith heating (oven/microwave) per unit mass and unit time, highlands and mare?	How well do we need to process the ice? How well does the removal of contaminants need to be (in order to perform electrolysis to extract O2 and H2, for drinking?, other?). Should/can contaminant removal be performed on the H2O or after O2/H2 are extracted?
How will oxygen be cryogenically stored and transported on the lunar surface? How will it be transferred between holding vessels, and how much leakage is acceptable? How long can it be stored and in what amounts? What are the risks?	What are the constraints of the new planetary protection rules for the permanently shadowed regions? (Let’s keep focused ONLY on the technology.)
Should oxygen extraction take precedence in the near term over tentative ice deposits, given volume, accessibility and extractability knowledge? This could potentially drive settlement site selection and infrastructure development.	How does water play into the Earth Orbit propellant supply chain? Market size/structure. Delivery and distribution systems. (Let’s keep focused on technology and needs. Put this into the “how much is needed” category of questions)
How much oxygen is needed to support a leaky (i.e. not fully regenerative) human habitat and life support systems? How will this change with growing populations?	How do we avoid establishing incentives for development that preclude systems that are great at producing/delivering water and don’t care about the oxygen?
Molecular Oxygen is 16x mass of hydrogen, what is the most efficient ground-based	What, other than water, is in demand commercially and is potentially produced on

transportation and storage method of O2?	the moon?
Are there lunar sources of Hydrogen that can be used with available oxygen in regolith minerals to produce water?	What are the energy requirements for extraction per unit mass of oxygen and water?
	What is the most useful form of energy (thermal, chemical, electrical, nuclear) for extracting oxygen and water? Useful needs to be better defined.
	What can water be used for? (that someone will pay for)
	Is there an architecture that can bootstrap ISRU propellant for sample return to Earth on a small CLPS lander? (possibly by using Water or Peroxide instead of cryogens?)
	Can we get competitive amounts of water from hydroxyl in the non-PSR regions?