The International Lunar Resource Prospecting Campaign: Growing the Collaboration. C.R. Neal[1], A. Abbud-Madrid[2], J.D. Carpenter[3], T. Chakraborty[4], A. Colaprete[5], B. DeWitt[6], B. Ehlmann[7], C. Espejel[8], K. Hadler[9], D. Heather[3], K.A. Hibbitts[10], K. Kim[11], J. Kleinhenz[12], S. Li[13], M. Link[14], M. Ohtake[15], G. R. Osinski[16], N. Petro[17], A. Salmeri[18], G. Sanders[19].

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Introduction: The International Lunar Resource Prospecting Campaign (ILRPC) has been detailed in [1] and represents an international lunar community effort to obtain data from lunar resources such that their reserve potential can be evaluated. We believe this is the critical next step in creating a sustainable and eventually permanent human presence on the Moon, developing a vibrant cislunar economy, and for yielding benefits to society back on Earth. Here, we look at the next stages of this campaign focusing on water resources, and the way forward beyond the aspirations outlined in [1].

Immediate Next Steps: In the initial effort [1], 9 exisiting and scheduled missions have been contacted (4 orbital, 5 landed) and asked to be part of the ILRPC. Orbital missions (LRO, KPLO, Chandrayaan-2, Lunar Trailblazer) and landed missions with definitive launch dates (VIPER, PRIME-1, PROSPECT) have been asked to share their data that inform us about water ice deposits on specific targets around the south pole. These data could be used to inform landed missions with future launch dates (e.g., LUPEX and the Canadian Lunar Rover missions) regarding the best landing site to target in terms of accessibility and water-ice potential. It is becoming evident that accessing the larger permanently shadowed regions (PSRs) at the south pole may not be possible, so we have targeted smaller PSRs as shown in Figure 1. These are around 5 potential Artemis landing sites (white squares) and will show the potential of each site for being able to harvest ***accessible*** water ice. These sites are also compelling if the surface water ice deposits identified in [3] are overlain on the Lunar Prospector neutron map [4] (Fig. 2) – see [5] for details.

Evolving the Campaign: Looking at the smaller PSRs with orbital data will yield a lot of targets to groundtruth with surface missions. Therefore, integrating new and existing relevant datasets will be critical to developing a "top ten/twenty/thirty" targets for ground truth missions. As can be seen from Figure 1, smaller

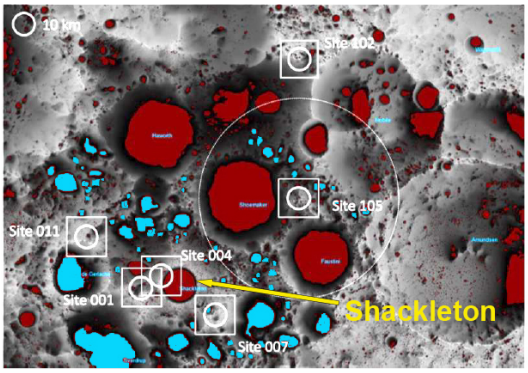

Figure 1: PSR targets for the initial orbital phase of the ILRPC shown in light blue. Adapted from [2]. Shackleton crater is shown for comparison with Fig. 2.

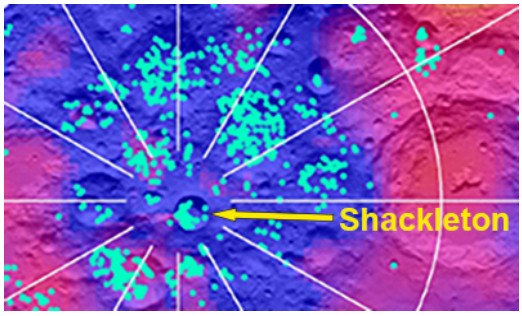

Figure 2: Lunar south pole surface water ice [3] overlain on Lunar Prospector neutrons [4], adapted from [5]. Shackleton crater is shown for comparison with Fig. 1.

PSRs are relatively close to 5 potential Artemis landing sites, so could "groundtruthing" be done, at least partially, by the astronauts? With the inception of the Lunar Terrain Vehicle (LTV) with Artemis V, groundtruth data regarding buried water ice ***around*** PSRs could be obtained once the astronauts have left through remote or autonomous operation for the properly instrumented LTV (e.g., carrying the VIPER instrument package). However, between now and the end of the decade, approximately 30 robotic lunar missions are funded and

under development, and 16 more have been proposed, but not funded. As these missions are further developed and as the integrated data from the south pole become available, efforts to include relevant future orbital and landed missions into the campaign will be initiated. This community-led, international lunar resource prospecting campaign is being conducted without developing any new missions, at least at this time. We are simply coordinating existing and scheduled missions.

Efforts are underway in the U.S. and Europe to start integrating currently available datasets for the relevant areas (Fig. 1). This requires uniting the science and mining communities to generate data products that inform both communities (e.g., [6]). Current efforts include collaborations between Lunar Station [7] and the University of Notre Dame in the U.S., and an initiative by the European Space Resources Innovation Centre (ESRIC) in Luxembourg [8].

Another evolution is in the standards for lunar resource prospecting and utilization. The Lunar Ore Reserves Standards (LORS) has been developed by co-author Espejel [9], which is built on the terrestrial Joint Ore Reserves Committee (JORC: Australian Institute of Mining & Metallurgy), the oil & gas industries, and the UN resource classification system [10]. But there are other terrestrial reporting standards that should be incuded (e.g., Canada, the National Instrument 41-101 General Prospectus Requirements [11]). The Planetary Resource Management System [12] is adapted from the terrestrial petroleum exploration model, and serves as a guideline for defining extraterrestrial prospecting, which ultimately provides criteria for the selection of human landing sites. However, the aim is to solidify international buy-in to LORS as the first extraterrestrial resource standards document in order to move lunar resources to igniting the cislunar economy and being in the critical path for exploration architectures. Therefore, part of evolving the campaign is to elevate LORS to be recognized by the Committee for Mineral Reserves International Reporting Standards (CRIRSCO – [13]). The latest objective of LORS is to become an ISO standard, which will allow LORS to become a truly inclusive, international, and living standard to be iterated as the ISRU industry evolves throughout time.

Two significant findings from two Lunar Surface Science Workshops (LSSWs) held on lunar resources [14,15] were that any ILRPC should be coordinated by a non-governmental organization. This is why the ILRPC is a community-driven initiative with currently over 40 people from around the world being affiliated with this effort. The second significant outcome was that a ***Potential Reserve Report*** for lunar resources should be constructed that would focus initially on polar volatile deposits, but could be expanded. This would use existing and available datasets to examine the reserve potential of different deposits. The product will not, in all probability, define reserves on the Moon, but will highlight what data are still needed in order to make a realistic, quantitative determination of reserve potential for polar volatile and other lunar resources. It will highlight specific areas for detailed exploration and through international coordination, plans for such data could be assembled. ESA has shown interest in developing this.

Data: Currently, the ILRPC operates with an open data policy as all of the missions currently included are government funded. However, part of the evolution could be that once needed critical datasets have been identified through the Potential Reserve Report, acquiring them may be attractive for commercially funded missions. For example, the need for higher resolution neutron data over the lunar poles has long been known and mission outlines have been published [16]. Also, once new and existing orbital data have been integrated and high priority sites identified, surface exploration of these sites could be of interest to commercial companies. Derived information becomes the revenue generator in this instance rather than the resource, and will require rethinking how relevant data are acquired and how access to this will be made available.

How much Data is needed? We know that the following are needed to make progress in understanding lunar water-ice deposits: 1) higher spatial resolution subsurface (1-3 meters) data; 2) higher spatial resolution IR spectral coverage of surface for identification of OH/H_2O and its form using key wavelength regions; 3) improved fine-scale temperatures. In a sub-group meeting in Korea (Nov. 2023), it was concluded that we should attempt to reveal "measured resources" of lunar water ice. It is also important that the data products show viability such that customers can be attracted in order to develop markets. One thing is evident – prospecting for lunar resources and estimating their reserve potential is essential for determining what level of investment in water-ice ISRU technology is warranted.

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