

STREAMLINING A CRITICAL PATH TO LUNAR SETTLEMENT. Kevin Hubbard,¹ Linda T. Elkins-Tanton,¹ Chris Hadfield,² School of Earth and Space Exploration, Arizona State University.¹ Chris Hadfield Inc.; University of Waterloo.² k.m.h@asu.edu¹, lelkinst@asu.edu¹, chris@chrishadfield.ca.²

Introduction: In order to succeed in establishing a sustainable lunar settlement, a detailed, comprehensive roadmap and complementary timeline is essential. There are numerous technology gaps related to human settlement that span across many disciplines. Though many of these gaps are doubtless being addressed in laboratories around the world, in the absence of published papers, finding documentation of researchers and the stage of development of the technology is often difficult.

There are multiple versions of exploration roadmaps that provide a wealth of information on our progress toward our exploration of the Moon and beyond [e.g. 1-3]. These roadmaps detail the essential first steps to lunar settlement and exploration, prioritize objectives for the lunar community, highlight technology that must be developed, and recommend specific investigations and initiatives to propel humans forward in that endeavor [4,5]. NASA has also released a series of detailed roadmaps for 15 distinct areas of technology development [6]. This effort also produced a poster of the major systems in lunar exploration currently being developed by NASA, demarcating developed technology for each system as well as what key sub-systems remain undeveloped [7].

While this information helps kickstart our efforts in expanding the presence of humans in space, there has been little effort in compiling a master list of key actors currently developing the necessary technology to resolve the major settlement goals and objectives highlighted in the major published roadmaps.

The Required Technology Categories: This project synthesized an extensive literature review of progress in lunar settlement and exploration with settlement focused objectives from *The Lunar Exploration Roadmap* published by the Lunar Exploration Analysis Group [4], critical technology gap assessments listed in The International Space Exploration Coordinating Group's *Global Exploration Roadmap* [5], and systematic gaps technology identified within NASA's Technology Roadmaps [6]. This resulted in a set of required technology categories on the path to human settlement listed below:

- 1) Water + Volatile Identification, Acquisition, Processing, and Storage
- 2) Power Generation and Handling
- 3) Lunar Transit
- 4) Surface Mobility and Operations

- 5) Habitat Infrastructure and Development
- 6) Environmental Control and Life Support System (ECLSS) Integration
- 7) Communication, Navigation, and Tracking
- 8) Crew Health Support and Performance

These eight major categories are considered the critical requirements to successfully sustain a permanent human presence on the Moon. Nested within each of the required technology categories are subsystems that, when completed, will help progress a required technology category toward "sufficient" completion.

Actors working on research that resolves any settlement related objective were identified during the literature review process and matched with its respective required technology category. One of the primary goals of this work is to guide the community to technology gaps. Highlighting objectives that have few or no actors may attract workers to those areas and thus speed up progress toward establishing a permanent human presence on the Moon.

A Critical Path To Lunar Settlement: This work seeks to sequence the required technology developments into a critical path to human settlement. An associated timeline will emerge and evolve as objectives are completed and as more actors become operative in the lunar settlement enterprise. A critical path to human settlement will deliver the following:

- 1) Present the stages of development for each major category and its sub-systems, producing an understanding of what is being done, and by whom.
- 2) Identify potential technology gaps to help focus future efforts on the critical path to lunar settlement as well as their secondary dependencies.

Participation of LPSC 2019 : The lunar settlement actor list is almost certainly not complete. Often, current progress in technology development is not available for public access. Thus, an up-to-date roadmap is dependent upon community input.

The authors invite LPSC 2019 attendees to contribute their knowledge of those working on technology development related to lunar settlement by stopping by during the poster sessions or via e-mail.

References: [1] Neal, C.R., Schmidt, G.K., Ehrenfreund, P., Carpenter, J.D., (2014) *Space Policy*, 156-162. [2] Sherwood, B. (2017), *Acta Astronautica*, 396-406. [3]. Mankins, J.C. (2009), *Acta Astronautica*, 1190-1195. [4] The Lunar Exploration Roadmap (2016). <https://www.lpi.usra.edu/leag/LER-2016.pdf>

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